A REVIEW OF THE SCOPE OF VECTOR CONTROL RESEARCH FOR THE ELIMINATION OF LYMPHATIC FILARIASIS IN INDIA

UNIVERSITY OF WASHINGTON STRATEGIC ANALYSIS, RESEARCH & TRAINING (START) CENTER

REPORT TO THE BILL & MELINDA GATES FOUNDATION

PRODUCED BY: ALISON WIYEH, MOHAMED ALBIRAIR & BARCLAY STEWART

SEPTEMBER 11, 2020

START CENTER
STRATEGIC ANALYSIS, RESEARCH & TRAINING CENTER
Department of Global Health | University of Washington

Executive Summary

Lymphatic Filariasis (LF) remains a significant cause of morbidity and mortality in India despite great efforts and achievements that have been made in the fight against this disease. It is thus critical that the national LF elimination program compliments mass drug administration with effective vector control management strategies that target Culex quinquefasciatus, the main vector responsible for the transmission of LF in India.

A team of researchers from the Strategic Analysis Research and Training Center (START) reviewed and narratively synthesize the findings on the range of vector control interventions that have been field tested or implemented with the goal of eliminating lymphatic filariasis in India. This was done to support ongoing collaborative efforts between the Indian LF Elimination Program, and the Bill and Melinda Gates Foundation to eliminate LF in India. Key lessons to be learned from past projects that have been successful are described. Finally, research gaps and action priorities are proposed.

Eighty-three reports, describing mostly Phase II – IV studies conducted in 18 Indian states were identified and included in this review. These reports described a range of biological, mechanical, environmental, chemical, integrated, and innovative vector control strategies that have been field tested in India. Overall, publications describing chemical measures (n=34) were the most common. However, many of these reports present epidemiological endpoints for Malaria without presenting these endpoints for LF. Reports on pilot studies (n=15) have generated evidence on the efficacy of integrated vector control strategies in small areas. It is important that additional pilot studies be conducted in communities that represent the diversity of Indian populations, geographies, vector distributions and environments to inform a national integrated vector management strategic plan. Vector control initiatives implemented at the community level should not only aim to educate the communities but strive to encourage community ownership through community driven planning, consensus building, participatory action research and budgeting. Finally, the LF elimination program should collaborate with researchers in identifying priority research questions that have the potential to significantly impact the program, to optimize resources.

We recommend that interviews with key stakeholders and communities should be conducted to provide more depth and context to the findings of this desk review. Renewed political commitment, intra- and inter-sectoral collaborations and capacity strengthening of vector control staff within the LF program will be critical as India makes giant steps to win the race against LF.

Integrated Vector Control

RESEARCH GAPS

- Community-led vector control initiatives were more successful than those that did not involve community stakeholders. However, studies generally did not systematically identify enablers, motivators, and barriers to community ownership of vector control programs. These critical components of integrated vector control programming need to be further elucidated.
- Pilot studies have generated evidence for efficacy of integrated vector control strategies in small areas. Research should now focus on assessing effectiveness, implementation, cost benefit and sustainability across larger areas.

ACTION PRIORITIES

- Community stakeholders should be included in the design and implementation of integrated vector management to increase the odds of success and sustainability.
- Develop a strategic integrated vector management plan that incorporates intra- and inter-sectoral collaboration, and achievable milestones that can be used to direct implementation partners, support advocacy efforts, and inform funding requirements.
- Support additional integrated vector control pilot studies in communities that represent the diversity of Indian populations, geographies, vector distributions and environments to inform a national integrated vector management strategic plan.

Biological Vector Control

RESEARCH GAPS

- The long-term epidemiological effect of biological vector control measures on LF burden when used alone is unclear due to lack of convincing evidence. There is a need to investigate and identify the most appropriate integration approaches of these measures with other vector control measures.

ACTION PRIORITIES

- Create a national LF vector control study registry and steering committee to facilitate a research strategy that avoids duplications and addresses the most topical questions.

- Identification and mapping of the different breeding sites of Culex quinquefasciatus, their locations and anticipated challenges should be conducted. This will determine what community and accessibility characteristics favor one vector control strategy over another.

Mechanical/Physical Control Measures

RESEARCH GAPS

- There is lack of convincing evidence around the long-term effects of using the measures described in the included studies (e.g. speedboats) in parts of India where lymphatic filariasis burden is high.

ACTION PRIORITIES

- Perform environmental impact analysis of mechanical control measures to ensure that potential benefits on vector control are balanced by other untoward effects on water ecosystems.

Environmental Control Measures

RESEARCH GAPS

- While interventions such as improved housing structures have the potential to decrease mosquito density, there is lack of convincing evidence around the cost, cost effectiveness, acceptability, and feasibility of interventions such as housing structures for the control of LF.

ACTION PRIORITIES

- Identify individual, household and community enablers and barriers to changing housing types before considering a larger study.
- Study the impacts of individual components of improved housing to determine if retrofitting existing structures may be timelier and more cost-effective.

Chemical Control Interventions

RESEARCH GAPS

- Chemical measures are effective against Culex quinquefasciatus. However, their long-term effects on the burden of LF is not sufficiently described as many of the included reports present epidemiological endpoints for Malaria without presenting these endpoints for LF.

ACTION PRIORITIES

- Evidence around the effects of chemical measures in LF control that are not covered by the malaria program should be identified and listed as priority research areas.
- Consider integrating LF Vector control committees with those of the malaria program.

Community Ownership

RESEARCH GAPS

- Traditionally, community engagement has been often limited to health education conducted over a limited period during the implementation of the research project. The impact of longer community and nationwide engagement initiatives such as the Swachh Bharat Mission, on community ownership of vector control management should be assessed.

ACTION PRIORITIES

- Community engagement strategies should not be limited to health education. Community driven planning, consensus building, participatory action research and budgeting and cooperatives should be employed as strategies to move vector control management initiatives from marginalization to community ownership.

Contents

Executive Summary **1**
Integrated Vector Control 2
Research Gaps 2
Action Priorities 2
Biological Vector Control 2
Research gaps 2
Action priorities 2
Mechanical/Physical Control Measures 3
Research Gaps 3
Action Priorities 3
Environmental Control Measures 3
Research gaps 3
Action priorities 3
Chemical Control Interventions 4
Research gaps 4
Action priorities 4
Community Ownership 4
Research Gaps 4
Action Priorities 4
Introduction **7**
Methodology **9**
Searching the literature 10
Data extraction, management, and synthesis 10
Ethical considerations 11
Results **12**
Key Landmarks in the History of the Indian LF Elimination Program 12
Review Findings and Discussions 15

Integrated Vector Control Measures 18
Biological Control Measures........ 28
Mechanical/Physical Control Measures 33
Environmental Control Measures........ 33
Chemical Control Measures 34
Other Interventions........ 38
Community Ownership 39
Conclusion........ 41
Appendix........ 42
References........ 43

List of Tables

Table 1: Study Inclusion and exclusion criteria 10
Table 2: Summary table of study characteristics and findings - Integrated vector control measures 26
Table 3: Integrated vector management components in included studies 27
Table 4: Summary table of study characteristics and findings – Biological measures 32
Table 6: The spectrum of community engagement to ownership 40
Table 7: Search strategies for PubMed, Embase and Central 42

List of Figures

Figure 1: Overlap in the global distribution of nine major vector-borne diseases: malaria, lymphatic filariasis, dengue, leishmaniasis, Japanese encephalitis, yellow fever, Chagas disease, human African trypanosomiasis or onchocerciasis. 7
Figure 2: Algorithm used to determine whether vector control is required for elimination of lymphatic filariasis in countries where the disease is endemic........ 8
Figure 3: Review process 9
Figure 4: Major milestones in the history of the India LF Program........ 14
Figure 5: Study flow chart 15
Figure 6: Distribution of included reports by state 16
Figure 7: Distribution of studies by Phases 17
Figure 8: Distribution of studies by control measure category 17
Figure 9: Indian Integrated Vector Management Strategy Used in the Filariasis Control Demonstration Project in Pondicherry 19

Introduction

Over half of the world's burden of lymphatic filariasis (LF) is transmitted by Culex quinquefasciatus and other man-biting mosquitoes of the Culex quinquefasciatus pipiens complex.[1] India is no exception to the burden caused by the Culex quinquefasciatus mosquitos as this vector is responsible for the transmission of LF parasites in India.[2] Globally, it is also responsible for the transmission of other illnesses (e.g., malaria) and there is an overlap in the burden of these vector-borne diseases as seen in Figure 1.[3] As a result, vector control strategies that target mosquitoes Culex quinquefasciatus have the potential to play a major role in the elimination of LF as well as other diseases whose transmission depends on the other mosquitos.[3]

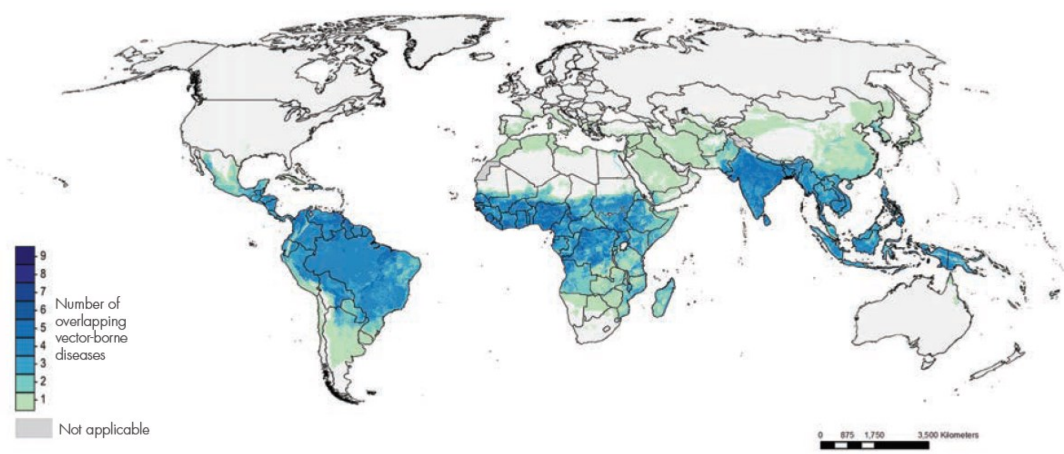

Figure 1: Overlap in the global distribution of nine major vector-borne diseases: malaria, lymphatic filariasis, dengue, leishmaniasis, Japanese encephalitis, yellow fever, Chagas disease, human African trypanosomiasis or onchocerciasis.

Source: Global Vector Control Response[4]

In the fight against LF, not all countries require vector control. In response, the World Health Organisation (WHO) has provided an algorithm to support national-level decision-making regarding whether to include vector control in their national programs (Figure 2). Considering the significant burden of LF in India, it is critical that the national LF control program compliments mass drug administration with effective vector control strategies.

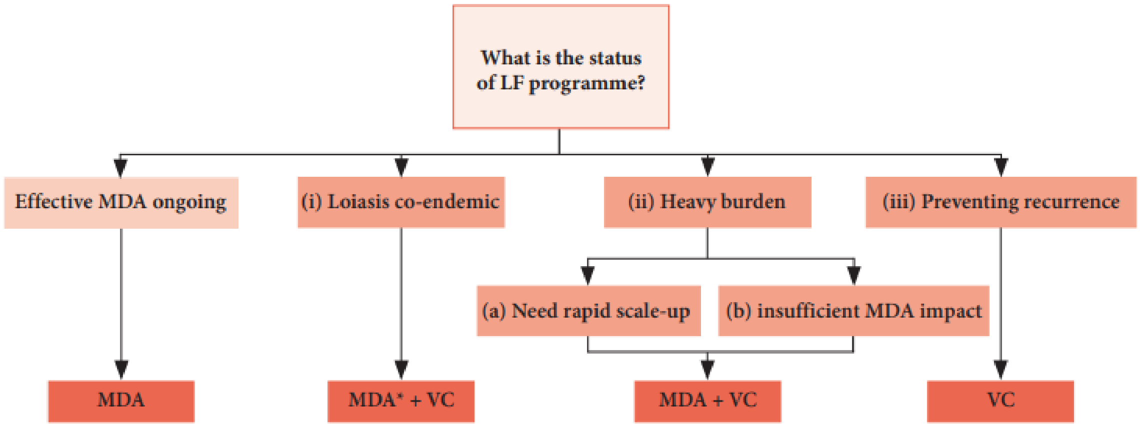

Figure 2: Algorithm used to determine whether vector control is required for elimination of lymphatic filariasis in countries where the disease is endemic

(Source: A Handbook for national elimination Programs)[5]

Integrated vector management is a rational decision-making process aimed to optimize the use of multiple, often parallel resources for vector control. It can be implemented through the use of a combination of interventions against a single disease or by using one or more interventions against more than one vector-borne disease.[1,3,4] Existing vector control measures have been categorized as environmental, mechanical/physical, biological, chemical and new technologies.[1] For vector management to be considered truly integrated, it needs to involve evidence-based decision-making, make use of the vector control measures aforementioned, and include intra- and inter-sectoral collaboration, advocacy, social mobilization, legislation and capacity building.[1]

India has made great gains in the fight against lymphatic filariasis through vector control. In this report, we review and describe the range of vector control interventions, used either alone or in combination, that have been field tested or implemented with the goal of eliminating lymphatic filariasis in India.

Methodology

Our approach to this review is schematically described in Figure 3. To achieve our aims, we began by rapidly reviewing the literature for reports that provided insights into the history of the LF elimination program in India. This enabled the research team to gain internal perspective of the Indian LF elimination program and guided the search strategy.

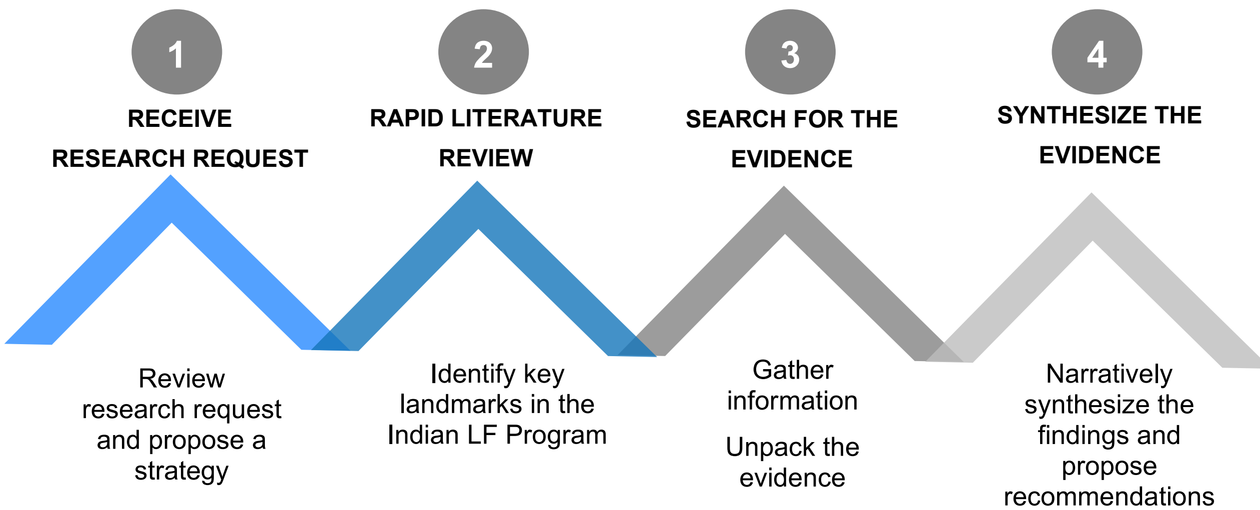

Figure 3: Review process

The methods in this scoping review were adapted from the framework for conducting a scoping study proposed by Arksey and O'Malley.[6] and modified by Peters et al.[7] We included reports that met the criteria summarized in Table 1.

Table 1: Study Inclusion and exclusion criteria

PICO ELEMENTS	INCLUSION CRITERIA	EXCLUSION CRITERIA
Study designs	Field studies: RCTs, before-and-after studies, time series, cohort studies, case-control studies, cross-sectional studies, case reports, and mixed method study designs	Laboratory based studies
Population	Studies conducted in India with focus on interventions that work primarily against the Culex quinquefasciatus mosquito and other LF mosquitoes	Studies conducted in other settings
Exposure	Interventions aimed at controlling the burden of the Culex quinquefasciatus mosquitos. These could include though not limited to environmental, mechanical, biological, and chemical interventions	Vector control that do not specifically mention the Culex quinquefasciatus mosquitos
Outcomes	Included studies needed to be at least Phase II studies	Phase I studies

Searching the literature

We developed a comprehensive search strategy to search MEDLINE through PubMed, EMBASE and Cochrane Central Register of Controlled Trials (CENTRAL) for all eligible records regardless of date, language, or status of publication (Appendix 1). We also conducted hand searches of the reference lists of key studies where necessary to identify important sub-studies. Initial searches were done on the 13th of February 2020 and updated on the 15th of July 2020 by a single investigator. Titles and abstracts of the retrieved records were de-duplicated in Mendeley and screened to identify potentially eligible records. Records whose titles and abstracts failed to meet our inclusion criteria were excluded at this stage. The full texts of potentially eligible reports were retrieved and assessed for inclusion by a single investigator. Potentially eligible reports whose full texts could not be retrieved were excluded.

Data extraction, management, and synthesis

Data from eligible reports were extracted into Excel using a pre-designed and refined data extraction form. This form enabled us to collect information on the publication details, setting and population where the study was conducted, as well as information about the intervention, outcome measures and findings. A framework published by the Pan American Health Organization (PAHO) described vector control interventions as being chemical, biological, mechanical/physical, environmental and new technologies.[8] We used this framework to classify reports into one of these vector control categories based in the description of the primary intervention being tested. Reports in which the use of a combination of vector control methods was described were classified as integrated vector control. Reports of field studies were further classified as Phase II studies if they described entomological outcomes, Phase III studies if they described both entomological and epidemiological outcomes and Phase IV if they described pilot implementation studies that assessed the effectiveness of the vector control intervention when used under ‘real-world’ conditions. These reports typically collected additional information on feasibility, distribution mechanisms, acceptability, cost, cost-effectiveness, and safety. Some Phase III and IV studies conducted in the malaria program described the effect of the interventions being tested on Culex quinquefasciatus. We classified these reports as Phase II studies if they reported only entomological outcomes for Culex quinquefasciatus. Finally, we conducted simple descriptive statistics of the included reports, described the scope of vector control research and the findings in the studies, highlight lessons to be learned, research gaps and key action priorities.

Ethical considerations

This review did not require formal ethical review and approval as it draws on data that is readily available on the public domain.

Results

Key Landmarks in the History of the Indian LF Elimination Program

The history of the Indian LF program was obtained from two reports by Agrawal 2006[8] and Sabesan 2010[9], a textbook examining the epidemiology, treatment and prevention of LF in India[2] and the website of the National Vector Borne Disease Control Program (NVBDCP).[10] The history is depicted in Figure 4.

1949 to 1954: Pilot projects on filariasis control in 8 villages in Odisha

1955: The National Filaria Control Program (NFCP) was launched. The main control measures were

- mass therapy with diethylcarbamazine (DEC)
- anti-adult mosquito measures with residual insecticides in rural areas
- recurrent anti-larval measures at weekly intervals in urban areas

1960 – 1995: Four independent assessments of the NFCP were conducted by expert committees of the Indian Council of Medical Research (ICMR):

- 1960: Failure of mass DEC administration due to side effects, community non-cooperation and ineffectiveness of insecticidal indoor spraying due to high resistance in the vector. The program was withdrawn from rural areas while in urban areas, antilarval measures continued to be the main control method
- 1970: Selective microfilariae carrier treatment with DEC was recommended as a compliment to antilarval measures. There was delimitation of the problem in non-surveyed districts and regionalization of control measures in contiguous areas
- 1984: The Assessment Committee recommended extension of NFCP to rural areas through the primary health care system
- 1995: Launching of a project in 1996 aimed at eradication of Brugia malayi infection, 100% central assistance for all vector-borne diseases, integrated vector control for all vector-borne diseases and model by-law adoption for effective control of vectors in domestic situations. It was recommended that: antigen and DNA-based detection of microfilaria be adopted, delimitation surveys in rural areas be initiated, medicated salt introduced in a Phased manner, and pyrethrum extract (2%) be supplied to filaria control towns where high numbers of malaria cases were being recorded to concomitantly tackle malaria transmission.

1996-97: Pilot projects of MDA with DEC were launched in 13 districts. The main strategy comprised of single day mass therapy (DEC) given annually, management of acute and chronic filariasis through referral services at selective centers, and information education communication to foster individual/community based protective and preventive measures for filaria control.

1997: 50th World Health Assembly resolution on global elimination of lymphatic filariasis by 2020. India was a signatory.

2000: Global Alliance to Eliminate Lymphatic Filariasis established. WHO launched the Global Program to Eliminate Lymphatic Filariasis with the following twin strategy:

- Interrupting transmission through annual mass drug administration, implemented to cover the entire at-risk population
- Alleviating the suffering caused by LF through morbidity management and disability prevention

2002: India sets the goal to eliminate LF by 2015. There was scale up of MDA in India to cover a population of 77 million in 2002 from 41 million during 1996–1997 by the Government of India's National Vector Borne Disease Control Program (NVBDCP).

2004: The Government of India launched annual mass drug administration (MDA) with a single dose of DEC to the population living at risk of filariasis except for children below 2 years, pregnant women, and seriously ill persons.

2007: Co-administration of DEC with albendazole for MDA.

2014 to 2015: Launch of the Hathipaon Mukt Bharat (Filaria Free India) initiative by the Ministry of Health and Family Welfare and the Swachh Bharat Mission (clean India) movement, which emphasized the importance of cleanliness and sanitary conditions in India for the control of diseases associated with poor sanitations.

2016: India launched Technical Assessment Survey to enumerate high microfilariae endemic areas in the country and implemented yet another MDA to increase chances of elimination.

2018: Launch of the Accelerated Plan for Elimination of Lymphatic Filariasis and initiation of Triple Drug Therapy (DEC + Albendazole + Ivermectin).

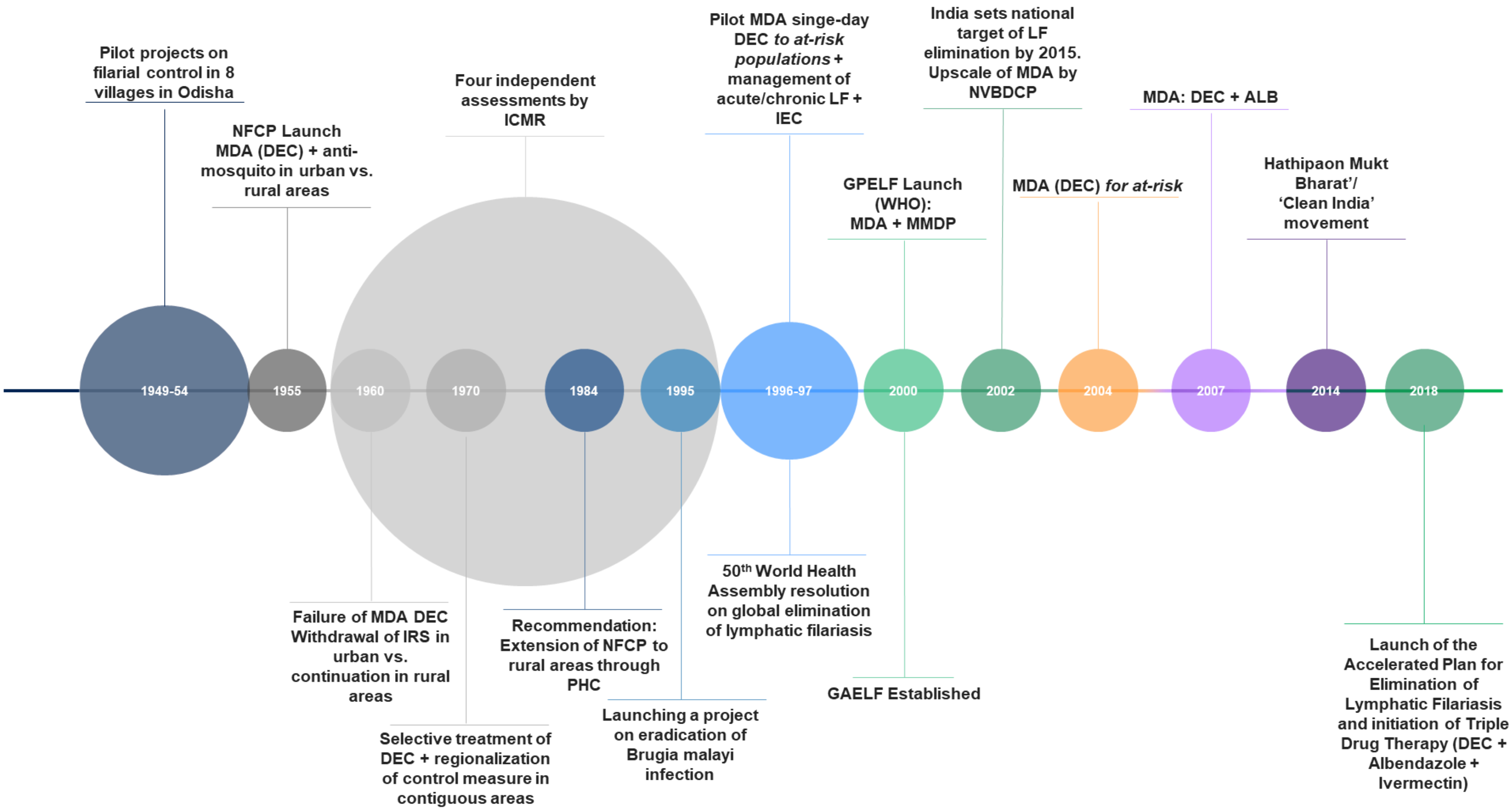

Figure 4: Major milestones in the history of the India LF Program

Review Findings and Discussions

Our search strategy identified 1229 records. After deduplication, we screened titles and abstracts of 707 records. Based on our predefined inclusion criteria, 90 potentially eligible reports were identified after full text review. Eight-three reports were included in this study. The screening process is summarized in figure 5.

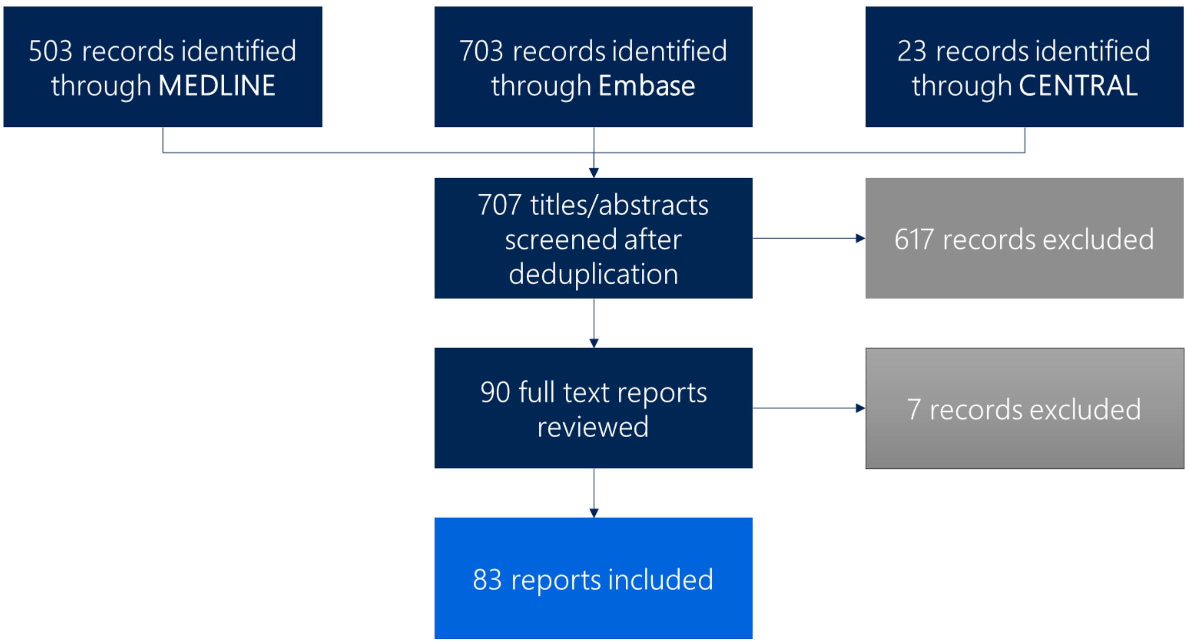

Figure 5: Study flow chart

The published reports covered 18 states in India, with Tamil Nadu (n=16), and Uttar Pradesh (n=13) having the highest number of reports. The statewide distribution is shown in figure 6. For eleven records, the states where the studies were conducted were unknown because the full texts of these reports were not accessible.

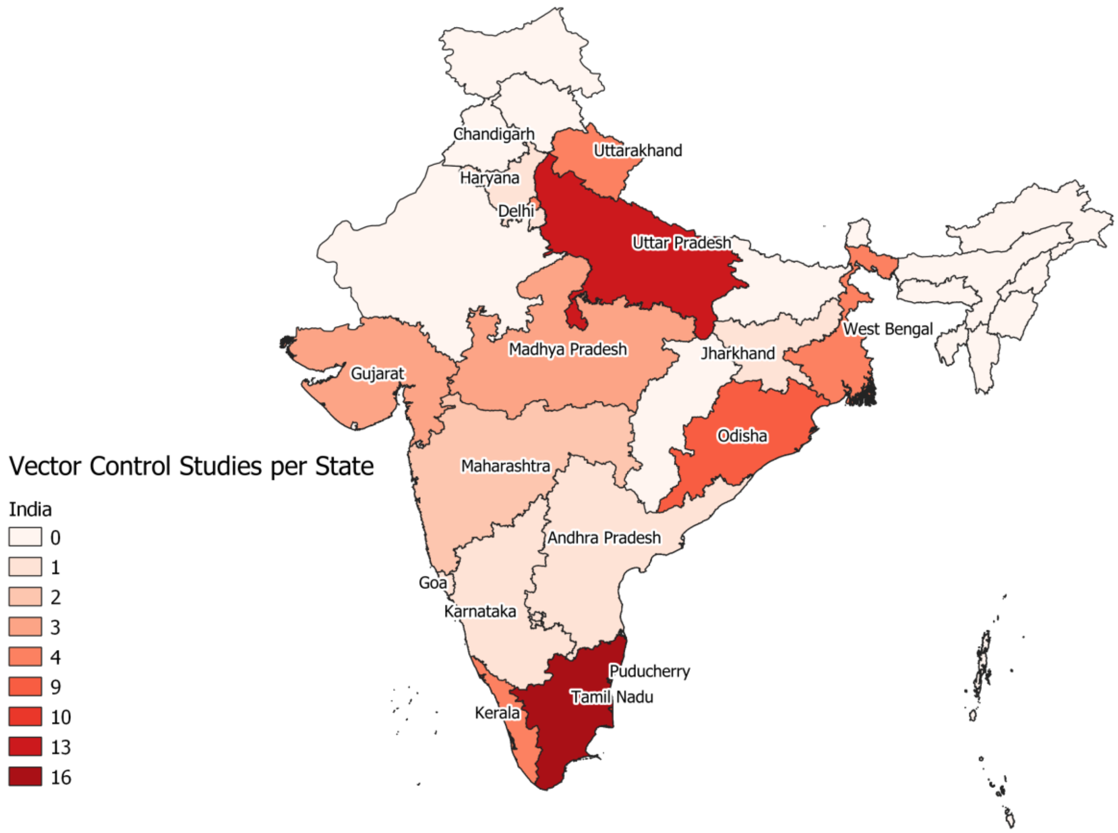

Figure 6: Distribution of included reports by state

The majority (n=62) of reports described Phase II studies, having only entomological outcomes for LF. There were some Phase III and IV studies that had epidemiological outcomes for Malaria and entomological outcomes for LF (n=9). They were classified as Phase II studies because of the focus of this project. Three reports were classified as “other” because they did not describe Phase II-IV studies. However, they presented information on cost effectiveness and population practices which we judged as being useful and complimentary to some of the reports we had included.

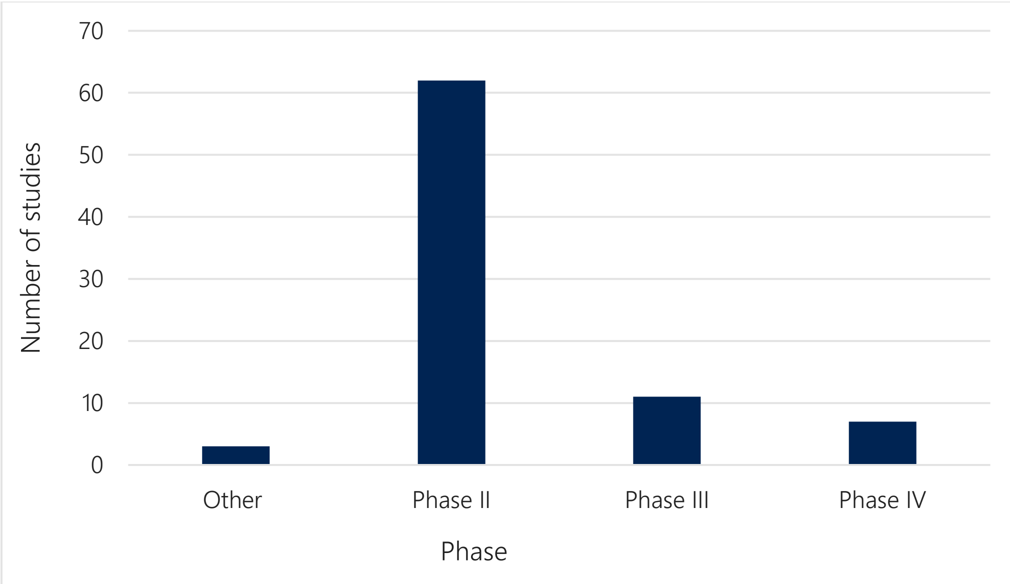

Figure 7: Distribution of studies by Phases

Most reports described chemical measures (n=34), followed by biological measures(n=22). Integrated measures were reported in 15 records that described four main projects.

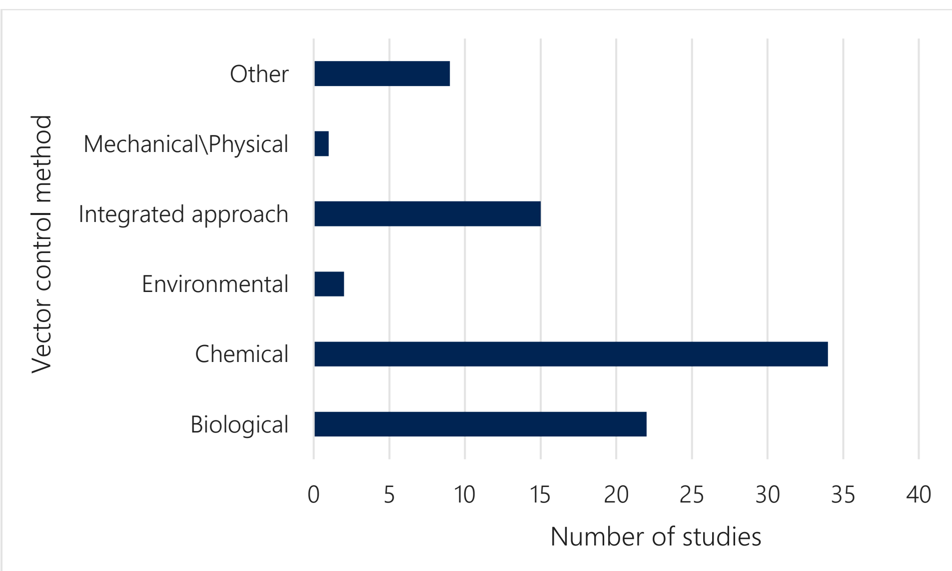

Figure 8: Distribution of studies by control measure category

INTEGRATED VECTOR CONTROL MEASURES

Fifteen reports described four projects where integrated vector control was implemented. Two of these reports lacked full texts and sufficient data; their findings could not be synthesized alongside the other reports.[11,12]

THE FILARIASIS CONTROL DEMONSTRATION PROJECT IN PUDUCHERRY – INTEGRATION OF BIOLOGICAL, SOURCE REDUCTION, CHEMICAL AND PHYSICAL METHODS

Seven reports published between 1988 and 1992 described the Filariasis Control Demonstration Project (FCDP) implemented in urban Pondicherry over a 5-year period (1981 to 1985).[13–18] It involved the integration of:

- Biological control: release of larvivorous fish such as Gambusia and Tilapia
- Source reduction: filling of breeding sites and promoting casuarina shrub planting
- Chemical control: use of insecticide such as Fenthion. Phenthoate, synthetic pyrethroids and juvenile hormone analogues were also used on an experimental basis.
- Physical methods: closing of wells, hermetic sealing of wells and septic tanks, and use of polystyrene expanded beads for preventing emergence and egg laying in wells, tanks, and cisterns.

The comparison area received the conventional method of vector control, which consisted of the treatment of breeding habitats with the larvicide malariol and the detection and treatment of microfilaria carriers implemented by the NFCP.[13] The project was built around the four main pillars of integrated vector management which include: adopting an Integrated approach, intra-sectoral and intersectoral collaboration, advocacy, social mobilization, and legislation and capacity building (Figure 9).

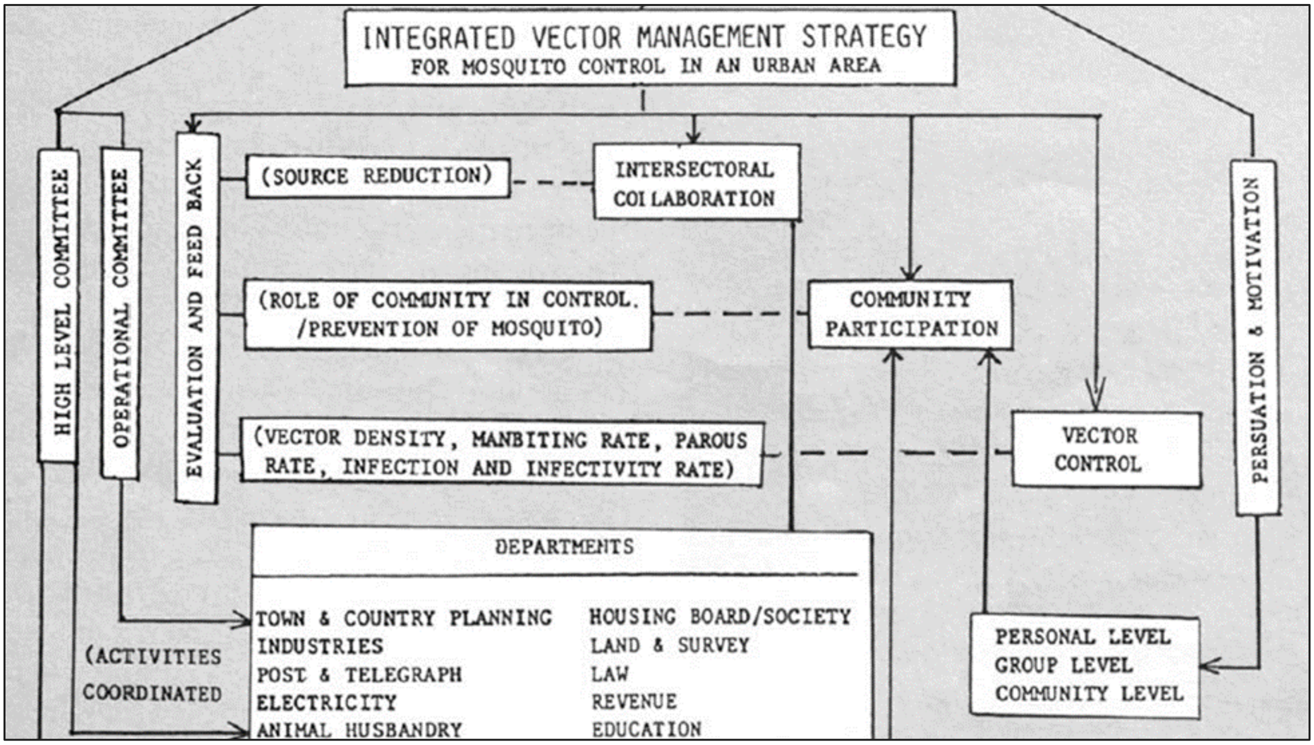

Figure 9: Indian Integrated Vector Management Strategy Used in the Filariasis Control Demonstration Project in Pondicherry

SUMMARY OF THE MAIN FINDINGS

After five years of implementing this project, the indoor resting density of Culex quinquefasciatus and transmission index for Wuchereria bancrofti were both reduced by 90%. The man-biting density of Culex quinquefasciatus and other mosquitoes were also reduced to low levels. In the post-intervention survey, blood analysis of 11.15% of the population of Pondicherry showed lower microfilariae rates, mean microfilaria density, annual incidence, and infectivity potential of human population when compared to pre-control values and to the prevalence in the nonintervention areas. Microfilariae rates in intervention zones were reduced from 8.93% to 6.35%. The biggest reduction in microfilariae rates was observed among children under 5 years, with over 91% reduction in microfilariae rate. It was estimated that 21 out of 1,000 children were prevented from becoming new microfilariae carriers because of this intervention. Annual and risk transmission indices reduced from 456.84 and 0.058 in the preintervention period to 89.59 and 0.007 in the post intervention periods, respectively.[17] Source reduction methods resulted in net cost savings of over USD 5841. Finally, there was high acceptability and community buy in.[19]

LESSONS LEARNED FROM THE FCDP: THE POWERFUL COMBINATION OF EXCELLENT LEADERSHIP AND EVIDENCE INFORMED INTEGRATED VECTOR CONTROL

The demonstration projects in Puducherry succeeded due to following reasons

1. Elaborate planning and preparation preceded implementation of the project

Extensive studies on the ecology of Culex quinquefasciatus in Pondicherry preceded the launching of the project. These provided in depth understanding of key factors and determinants of disease burden such as:

- Mosquito peak seasons: the average daily emergence was found to range from 172900 mosquitoes in November to 9.6 million in the post-rainy month of January.
- Breeding sites: Drains, cesspits, pools, wells, and large swamps were extensively studied. Drains were found to contribute up to 90% of mosquito emergence in the post-monsoon months, while during the rainy season the cesspits contributed to 45%, drains to 35% and wells to 17% of total mosquito emergence.
- Enabling factors: Rapid unplanned urbanization with increased movement of microfilaria carriers and susceptible populations into the town, increase in population density, and prolonged mismanagement of the environment.

2. Intra and intersectoral collaboration

Effective collaboration between LF researchers and program implementers was established. Also a multi departmental approach to vector control was initiated. Agencies with some role in creating or preventing conditions for mosquito breeding were enlisted and two coordinating committees were formed: A high level committee, including all heads of departments concerned with development work and an operational committee that coordinated the day to day implementation of the project. The role of the health department was mainly to take the lead and initiate actions on the lines indicated.

3. Community education and involvement

Community education and awareness raising was done using various media such as hoardings with pictorial themes, wall posters, films, and cinema slides. Group leaders and residents' associations were educated on the dangers of unsanitary conditions.

4. Legislative measures

This involved the enforcement of different by-laws for control of mosquito breeding sites though it is unclear from the literature exactly which laws were used.

5. Use of evidence-based interventions that work that are known to work

Experience under the Malaria Eradication Program had shown that indoor residual sprays had no effect in controlling Culex quinquefasciatus, so they opted for other interventions that had proven to be effective.

6. Tailoring of the vector control approach by using integration of multiple measures

They used source reduction as their main strategy. However, larvivorous fishes were used where their survival was not endangered. They also closed off wells and septic tanks and used polystyrene beads to prevent emergence and egg laying in wells, overhead tanks, and cisterns.

7. Exemplary management and competent staff

The project efforts were efficiently coordinated. All operations followed a strict schedule, and the progress of the project was reviewed every week. The project team worked with competent staff and ensured that there were adequate facilities in place for the implementation of the project. Responsibilities were delegated at all levels, with evaluation and feedback of results into the operational Program. There was flexibility in both decision making and operational plans depending on changing needs. Encouragement and support from top administrators played a key role in motivating staff involved.

MDA ALONE VERSUS MDA PLUS INTEGRATED VECTOR CONTROL PROJECTS IN TAMIL NADU

Two projects implemented in Tamil Nadu are described (Table 2). The first was implemented between 1995 and 2005 and compared the effect of using MDA alone to MDA plus integrated vector control in areas of Cuddalore and Villupuram.[20–24] In 1995, Group A villages had MDA alone (diethylcarbamazine plus ivermectin), Group B received the same MDA in combination with investigator-led vector control using expanded polystyrene beads, modification of soakage pits and introduction of larvivorous fish in unused wells; and Group C received only placebo tablets. Between 1997 – 1999, Groups A and B received no MDA. However, community-led vector control was implemented in Group B after 1997. The placebo group was given anti-filarial drugs in 1999, which led to a dissolution of the placebo arm thereafter.[21]

The second project ran between 2008 and 2013. Group A villages received MDA alone, Group B were administered MDA + integrated vector management (EPS + larvivorous fishes) and Group C was assigned MDA + integrated vector management (EPS + Pyrethroid-impregnated curtain + larvivorous fishes).

SUMMARY OF THE MAIN FINDINGS

For the first project, evaluations done in 1997 showed a marked reduction in microfilariae for Group A and B by 88.1% and 91.8% respectively and only by 27% in the placebo group. In 1999, the gains of MDA were sustained in Group B, which had ongoing community-led vector control efforts, while the microfilaria prevalence and intensities resurged in Group A where MDA had been interrupted. Evaluations in 2005 showed that vector density greatly decreased in villages where vector control was used as an adjunct to mass drug administration and almost no infective mosquitoes were found in the small numbers remaining. Filarial antigenaemia was low and continued to decrease significantly in the age group 15–25 years in villages that received mass drug administration with vector control in contrast to villages that received only mass drug administration[21]

For the second project, decline in antigenaemia prevalence was higher in MDA + integrated vector control groups compared to the MDA alone group. Vector density dropped significantly in both the integrated vector control arms and no transmission was observed during post-integrated vector control period. Almost 53.8 and 75.8% of the cesspits in MDA + EPS and MDA + EPS + Pyrethroid-impregnated curtain + larvivorous fish arms were closed by the householders due to the enhanced awareness on vector breeding.

BIOENVIRONMENTAL CONTROL USING MAJOR SOURCE REDUCTION + EPS + BIOLARVICIDES + LARVIVOROUS FISH IN HARDWAR

A bioenvironmental model involving major source reduction and development work to control malaria at Bharat Heavy Electricals is described by Virendra and colleagues.[25] This was an intervention involving significant intra- and inter-sectoral collaboration. The Civil Maintenance Department carried out source reduction work by filling pits, low lying areas and ditches with fly ash, construction of stand posts and proper drainage outlets, mosquito proofing overhead tanks, and preventive maintenance of the water and sewage systems. EPS, biolarvicides and larvivorous fish were also applied to varied mosquito breading sites.

SUMMARY OF THE MAIN FINDINGS

Although the main focus of this study was on the effect the intervention had on the burden of malaria in the study area, the vector densities of mosquitoes including Culex quinquefasciatus mosquitoes in experimental and control villages were significantly different, with lower densities in the intervention village. During the period when this intervention was implemented, about US$ 40,000 was spent annually for fly ash disposal. Using this fly ash for source filling made the intervention cost saving.[25]

Two key highlights of this project were the strong and efficient intra- and intersectoral collaboration and the successful engagement and involvement of the community in the implementation of the vector control interventions.

LESSONS LEARNED FROM THE HARDWAR PROJECT: EXCELLENT INTERSECTORAL COLLABORATION

The strength of the vector control project using bioenvironmental strategies implemented at Bharat Heavy Electricals, Hardwar was in their ability to rally and collaborate with different key sectors and stakeholders:

1. The Civil Maintenance Department of BHEL: Carried out major source reduction work by filling pits with industrial waste, mosquito proofing of overhead tanks and preventive maintenance of the water supply and sewerage system.
2. Water supply and sewerage department of BHEL: Construction of standpipes and proper drainage around them
3. The medical and publicity departments: Application of biological measures, health education and project supervision
4. Other government agencies, such as Social Forestry, the Indian Army, the Nonconventional Energy Development Agency, and the Rural development Centre, provided additional support for developmental activities during the project

THE FILARIASIS CONTROL MOVEMENT

One study published in 1992 described the Filariasis Control Movement's (FILCO) project.[26] Due to lack of studies that described this project, we searched for other narrative records, as well as information from Indian websites to provide more details to the lone article we had identified.[27–29] The VCRC implemented an intervention which comprised of vector control using weeding, providing the people with fingerlings of fast-growing edible and weedivorous fish for income generating pisciculture, intensive health education and free mass drug treatment including management of chronic cases.[26,27,29] Prior to the intervention, the people had used Pistia and other weeds which are excellent breeding sites for Culex quinquefasciatus as manure for their coconut trees. The VCRC convinced them to replace Pistia with sunhemp, a healthier and effective option. Pistia was also grown in ponds from which the people fetched water for household use as they believed the weeds kept the water cool especially during the summer. The VCRC convinced the people to destroy the weeds and rear fish instead.

SUMMARY OF THE MAIN FINDINGS

Man biting rate and resting density showed reduction in the intervention area compared to areas with no intervention. A report suggests that mosquito density plummeted by 84% and the proportion of carrier mosquitoes dropped by 63%.[28] Mosquito infection and infectivity rates also declined to almost zero in the operational areas and remained high in nonintervention areas. Within five years when the transmission chain was broken, and no new microfilaria positive cases were recorded in children below five years of age.[27] There was also an increase in economic prosperity in the communities involved. As a result of the income generated by the fish, the Program gained popularity.

LESSONS LEARNED FROM THE FILCO MOVEMENT: MOVING FROM MARGINALIZATION TO COMMUNITY OWNERSHIP OF VECTOR CONTROL PROGRAMS

The FILCO movement project launched in Kerala in 1986 successfully demonstrated the power of innovative strategies in community engagement. Key lessons are summarized:

1. Intensive health education that was tailored to the audience

The VCRC team understood that misinformation was a primary reason why the people used Pistia stratiotes and other weeds which are excellent breeding sites for Culex quinquefasciatus as manure for their coconut trees. These weeds were also grown in ponds that supplied water for household use as the people believed it to be useful in keeping the water cool. Wide intensive health education, that was tailored to the different audiences was conducted through house to house education, schools, and community activities.

2. Economic empowerment through pisciculture

This was their most powerful tool. Fingerlings of fast-growing edible and weedivorous fishes were given to people who were interested. As a result of the income generated by the fish, the Program gained popularity. The National Bank for Agricultural and Rural development even offered loans to farmers wishing to make economic use of weed-infested ponds to reduce mosquito breeding sites.

3. Provision of effective healthier alternatives

Before the intervention, Pistia was used as manure for coconut trees. During the intervention, the people were convinced to replace Pistia with sunhemp, a healthier source of manure which was later adopted by the Kerala Department of Agriculture.

4. Capacity building

Motivated community members were identified and trained on how to prepare blood smears and administer drugs in the context of the LF program. As of 2015, the Filaria control movement reported over 96 member-bodies and 10,000 volunteers involved at various levels in the fight against LF. This moved some aspects of vector control from the government to the communities, enabling a more horizontal approach instead of the typical vertical approach seen in many programs.

5. Intra and intersectoral collaboration

The VCRC successfully worked with school authorities and other public organizations such as the urban basic services, integrated child development services and Rural Functional Literacy program. Also, the movement which began as an amalgamation of six voluntary organizations has grown over time. Collaboration and good leadership have been important in sustaining it.

6. Successful Integration of vector control strategies

They efficiently combined weeding, provision of fingerlings of fast-growing edible and weedivorous fish for income generating pisciculture, intensive health education and free mass drug treatment including for chronic cases as a vector control strategy.

Table 2: Summary table of study characteristics and findings - Integrated vector control measures

STUDY ID	YEAR	INTERVENTION	FINDINGS
FCDP [13–18]	1981-1985	Biological + source reduction + chemical + physical + Legislative interventions	Indoor resting density, man-biting density of Culex quinquefasciatus and transmission index for Wuchereria bancrofti were significantly reduced. Incidence of microfilaraemia reduced by 60%. Cost effective and highly acceptable by the community
MDA alone vs MDA plus integrated vector control[20–24]	1995-2005	**1995-1996** Group A: MDA (DEC + ivermectin) Group B: MDAs + vector control using EPS, larvivorous fish and modification of soakage pits with active involvement of the community Group C: Placebo tablets **1997 – 1999** Group A: No intervention Group B: Community led vector control Group C: Placebo tablets **1999 – 2005** Group A: MDA Group B: MDA + Community led vector control	Evaluation in 1997: marked reductions in MICROFILARIAEP for Group A and B by 88.1% and 91.8% reduction respectively and only 27% for placebo group. Evaluation in 1999: The gains of MDA was sustained in group B which had ongoing community led vector control being implemented, while resurgences occurred in Group A Evaluation 2005: Vector density significantly decreased in villages where vector control was used as an adjunct to mass drug administration and almost no infective mosquitoes were found in the small numbers remaining. Filarial antigenaemia was low and continued to decrease significantly in the age group 15–25 years in villages receiving mass drug administration with vector control in contrast to villages receiving only mass drug administration
	2008-2013	Group A: MDA alone Group B: MDA + IVM (EPS + larvivorous fishes) Group C: MDA + IVM (EPS + PIC + larvivorous fishes) Implementation and monitoring of integrated vector management was carried out by the community	Significant reductions in entomological measures were observed in both the community and vector populations. Decline in antigenaemia prevalence was higher in MDA + IVM as compared to MDA alone arm. Vector density dropped significantly in both the IVM arms, and no transmission was observed during post-IVC period. Almost 53.8 and 75.8 % of the cesspits in MDA + EPS and MDA + EPS + PIC arms were closed by the householders, due to the enhanced awareness on vector breeding
Bioenvironmental control[25]	1987-1995	Major source reduction using fly ash + EPS + biolarvicides + larvivorous fish	The vector density in the township was significantly lowered compared to that of a control area. The intervention was feasible, appropriate, and cost effective
FILCO movement project	1986	Weeding, provision of fish fingerlings for pisciculture, intensive health education and free mass drug treatment including for chronic cases	Man biting rate, resting density, infection and infectivity rates reduced in the intervention area compared to control. Within five years no new microfilaria positive cases were recorded in children below five. There was also an increase in economic prosperity in the communities involved.

INTEGRATED VECTOR MANAGEMENT COMPONENTS

The main components of integrated vector management are described in the four different projects that used integrated vector control strategies (Table 3). The authors highlight community acceptance, involvement, and ownership as being key to the success of the projects.

Table 3: Integrated vector management components in included studies

STUDY	INTEGRATED APPROACH	INTRA-SECTORAL AND INTERSECTORAL COLLABORATION	ADVOCACY, SOCIAL MOBILIZATION, AND LEGISLATION	CAPACITY BUILDING
FCDP studies	Integration of biological, source reduction, chemical and physical methods for vector control	A multi-departmental approach to filariasis control through vector control was initiated. Two committees formed enlisted all the agencies with some role in creating or preventing conditions for mosquito breeding	Use of various media to educate the public on the dangers of unsanitary conditions, orientation training for group leaders and residents' associations. Efforts were also made for the enforcement of different Civic laws	Not described
MDA vs MDA+ integrated vector control	Integration of expanded polystyrene beads, modification of soakage pits and introduction of Larvivorous fish in unused wells for vector control	Not described	The investigators implemented vector control activities with effective community involvement, initially. In the later stages, from November 1997, the villagers themselves took over control activities on their own	Not described
Bioenvironmental	Integration of major source reduction, EPS, Biolarvicides, larvivorous fish	Close cooperation with various departments including civil maintenance, water supply and sewerage, medical, and publicity departments, as well as the local community enabled the implementation of vector control	Emphasis was laid on involving the local community in the vector control program through Health education and community participation	Not described
FILCO movement	Weeding, income generating pisciculture, intensive health education and free mass drug treatment	Worked with school authorities and other public organizations such as the urban basic services, integrated child development services and rural functional literacy Program	Wide intensive health education, that was tailored to the different audiences was conducted through house to house education, schools, and community activities	Motivated community members were identified and trained on how to prepare blood smears and administer drugs

Despite the successful implementation of all four integrated vector control projects described, none of the reports described plans on how to efficiently scale up and sustain these interventions. A clear understand of contextual enablers, motivators, and barriers is needed to support adaptation, scale up, community ownership and maintenance of these intervention in different settings across India.

BIOLOGICAL CONTROL MEASURES

Twenty-two reports examined the effect of biological control measures on mosquitoes. Three reports targeted Mansonia mosquitoes, six targeted various species of the Anopheles mosquito and Culex quinquefasciatus, five targeted Anopheles, Aedes and Culex quinquefasciatus and eight targeted Culex quinquefasciatus species only. The biological measures examined included entomological fungi, biological larvicides and natural enemies.

ENTOMOLOGICAL FUNGI

A Phase II study published in 2008 examined the effect of Chrysosporium lobatum (i.e., a deuteromycetous fungus) on mosquito density in pools in Agra in Uttar Pradesh. Two pools (A & B) situated near a cattle shed, two cement tanks (C & D) and one pool containing irrigated water (E) were inoculated with a single concentration (10^6 conidia/mL) of Chrysosporium lobatum.[30] A sixth pool was used as a control pool.

SUMMARY OF THE MAIN FINDINGS

The effectiveness of the conidia was inversely correlated with the following water parameters: total dissolve solids, hardness, chemical oxygen demand and conductivity. Higher larval mortality was observed in the pools (A, D and E) with water quality that was lower in total dissolve solids, hardness, chemical oxygen demand and conductivity. Salinity and pH did not appear to influence the efficacy of Chrysosporium lobatum against Culex quinquefasciatus. Larval populations started to decline significantly on average 15 days after application of conidia, with the highest percentage of larval mortality recorded in test pool C and the lowest in test pool B, 45 days after inoculation.

Entomological fungi may be a useful biological control in certain bodies of water, however, there is paucity of evidence around the effectiveness of this intervention, as only one Phase II study was identified that examined the effectiveness of entomological fungi. Larger studies with different types of entomological fungi should be considered if the LF program wishes to add this intervention to the national integrated vector management plan.

BIOLOGICAL LARVICIDES

Thirteen reports published between 1993 and 2018 described studies conducted using the biological larvicides Bacillus sphaericus, Bacillus thuringiensis and Spinosad.

1. Bacillus sphaericus and thuringiensis

Five Phase II studies published between 1993 and 1998 reported on the use of Bacillus Sphaericus.[31–35] Different formulations of Bacillus sphaericus (Spherimos and Vectolex) were compared to placebo in another study.[33] In one study, the authors used a slow-release formulation of Bacillus thuringiensis pellets[36] and in another one, they used a fly ash-based water dispersible formulation.[37] One study compared Bacillus Sphaericus to routine antilarval measures.[32] Two reports whose full-text were no accessible were identified. The authors of these reports described using Bacillus Sphaericus but the comparison was unclear.[34,35]

Regrading Bacillus thuringiensis, seven reports published between 1993 and 2018 described the use of various formulations and dosages of this intervention compared to no treatment in the main comparison arms in field trials.[36–42] In one report, Bacillus thuringiensis was compared to Bacillus Sphaericus.[31]

SUMMARY OF THE MAIN FINDINGS

There was significant reduction in the density (> 95%) of anopheline and culicine larvae within 24-48 hours when Bacillus Sphaericus and thuringiensis were used, with the effect lasting on average for 2-4 week depending on where the intervention was tested. The greatest impact of Bacillus thuringiensis and Bacillus Sphaericus was seen in clean water habitats such as cement tanks and cesspools and the least impact and residual activity were observed in polluted drains and irrigation channel even despite the use of higher inoculation doses.

One report of Bacillus thuringiensis use had outstanding results: In moderately polluted water, application of a 1 part per million of Bacillus thuringiensis pellet maintained a mean larval reduction of 90% for a period of 35 days, which is a much longer residual effect than reported by other studies using this intervention.[36]

Weekly to fortnightly reapplications were required due to the short-lived effect of most biological larvicides, especially Bacillus sphaericus and thuringiensis. This has programmatic implications in terms of manpower and stock management that should be considered when including these interventions in the LF Program. A decline in the efficacy of biological larvicides in some Culex quinquefasciatus breeding sites was observed after repeated spraying, which needs to be monitored. Difficult terrain and inaccessibility were also highlighted as barriers to effective spraying and alternative vector control interventions should be considered in such areas.

2. Spinosad

One study conducted in Tamil Nadu compared the effect of several doses of Spinosad 20% emulsifiable concentrate (25, 50, 100 and 150 mg active ingredient/m^2) on Culex quinquefasciatus immatures to 12% suspension concentration and placebo when applied to cesspits, drains and abandoned wells.[43]

SUMMARY OF THE MAIN FINDINGS

The 20% emulsifiable concentrate caused >90% reduction in the density of immatures for 7-14 days in cesspits, 10-17 days in drains and 14-30 days in abandoned wells at all dosages tested. At lower dosages of 25 and 50 mg active ingredient/m^2, >90% reduction in the density of immatures was observed for one week in cesspits and street drains and for two weeks in abandoned wells. The effect observed was dose dependent with higher dosages of 100 and 150 mg active ingredient /m^2 yielding 1.4 to 2 times more potent results than the lower dosages of 25 and 50 mg active ingredient/m^2. Unlike biological larvicides, Spinosad 20% emulsifiable concentrate had a longer residual effect in drains (10-17 days) and abandoned wells (14-30 days) than in cesspits (7-14 days).

NATURAL ENEMIES

Eight reports published between 1989 and 2018 studied the biological control of mosquitoes with natural enemies. Seven of these reports were Phase II studies reporting on entomological outcomes and one report was an economic analysis. The economic analysis described the cost benefit of fish culture in Kerala state.[44]

1. Fishes: larvivorous and weedivorous fishes

Four reports studied the effects of using larvivorous fish such as Poecilia reticulata,[45,46], Gambusia affinis[47] and Colisa fasciatus [48] for the control of Culex quinquefasciatus. Three reports examined the effect of weedivorous fishes such as Osphronemus goramy.[44,49,50]

SUMMARY OF THE MAIN FINDINGS

Mixed results were obtained from reports of larvivorous fishes, especially for Poecilia reticulata. An earlier study in 1992 reported that it was efficient in reducing mosquito populations.[46] However, a more recent study found that it failed to feed on Culex quinquefasciatus larvae in polluted drains but seemed to be larvivorous when placed in drinking water sources.[45] This highlights that the environment in which the fishes are introduced may play a key role in determining their effectiveness. Other fishes such as Colisa fasciatus, Oreochromis mossambica, Esomus danricus, Oryzias melastigma, Puntius sophore, Puntius ticto, Rasbora daniconius, Rasbora elegans and Aplocheilus panchax were reported to be highly larvivorous.[48]

The use of weedivorous fishes resulted in significant reduction in vector breeding and re-infestation in intervention sites compared to the control ponds, with >80% of ponds being kept free from weeds. Culture of weedivorous fishes also enabled the community to gain approximately 2500 USD each from

763 fishponds with Chinese grass carp and 1000 fishponds under polyculture with Catla catla, Cyprinus carpio, Labeo rohita, Labeo fimbriatus, Cirrhina mrigala and Ctenopharyngodon idella.

Fishes face threats from fishing, human interference, loss of habitat, overexploitation, pollution, siltation, trade, and diseases. Their successful use in vector control programs will require identification of measures to protect them.

2. Mosquito ferns

One report described the effect of the fern Azolla pinnata on pools, ponds, wells, rice fields and drains known to be breeding sites for Culex quinquefasciatus.[51]

SUMMARY OF THE MAIN FINDINGS

The use of Azolla pinnata did not yield satisfactory results. Although Anopheline breeding was almost completely suppressed (0-1.6/dip) in pools, wells and ponds completely covered with Azolla pinnata, Culex quinquefasciatus was not adequately inhibited in any habitat, despite reduction in immature density.

Table 4: Summary table of study characteristics and findings – Biological measures

TYPE OF CONTROL MEASURE	INTERVENTION	DESCRIPTION OF INTERVENTION	FINDINGS
Entomological Fungi	Chrysosporium lobatum[30]	Pools and cement tanks were inoculated with a single concentration (10^6 conidia/mL) of Chrysosporium lobatum	Larval populations declined significantly 15 days after application of conidia. The effects of conidia on were correlated with the hardness, TDS, COD and conductivity of the water
Biological Larvicides	Bacillus sphaericus[31–35]	Various doses ranging between 0.25g/m^2 and 4 g/m^2, were applied to different mosquito breeding sites	Significant (> 95%) reduction in larval density was reported within 48 hours across studies and the effect lasted for 2 -4 weeks. Effect varied depending on where it was sprayed, with seemingly better and longer effects when sprayed in pools and wells compared to irrigation channel. Weekly reapplications were required due to the short-lived effect. There was a decline in efficacy after repeated spraying.
	Bacillus thuringiensis[36–42]	Various doses ranging between 0.5 ml/m2 and 4 g/m2, were applied to different mosquito breeding sites	Significant (> 80%) reduction in larval density with doses of 1 ml/m^2 in comparison to control area, with effects lasting 1-2 weeks was reported. Greatest impact seen in clean water habitats such as cement tanks and cesspools. Least impact and residual activity observed in polluted drains even despite the use of higher doses. In one study, 1 ppm pellet maintained a mean larval reduction of 90% for up to 35 days in moderately polluted water and 21 days in highly polluted water.
	Spinosad[43]	Spinosad 20 % was tested at doses of 25, 50, 100 and 150 mg active ingredient/m^2 versus Spinosad 12% at the optimum field application dosage of 50 mg ai/m	The 20% EC caused 90-100% reduction in the density of immatures for 7-14 days in cesspits, 10-17 days in drains and 14-30 days in abandoned wells at all dosages tested. At lower dosages of 25 and 50 mg ai/m^2 , >90% reduction in the density of immatures was observed for one week in cesspits and street drains and for two weeks in abandoned wells. The effective duration of control provided by the higher dosages, 100 and 150 mg ai/m^2 was 1.4 to 2 times greater than the lower dosages, 25 and 50 mg ai/m^2.
Natural Enemies	Larvivorous fishes[45–48]	The larvivorous effects of several fishes such as Gambusia affinis, Poecilia reticulata and Colisa fasciatus amongst others were assessed.	Fish such as Poecilia reticulata and Gambusia affinis yielded mixed results depending on the habitat where they were tested, with high potency in drinking water sources and least in polluted drains. Other fishes such as Colisa fasciatus, Oreochromis mossambica amongst others were reported to be highly larvivorous.
	Weedivorous fishes[44,49,50]	The effect of phytophagous fishes in the control of mansonioides mosquitoes was assessed.	There was significant reduction in vector breeding and re-infestation in intervention sites compared to the control ponds, with >80% of ponds being kept free from weeds. The intervention also generated substantial finances for the community.
	Mosquitoferns[51]	The utility of Azolla pinnata for the control of mosquito breeding in different habitats was assessed	The breeding of Culex quinquefasciatus was not satisfactorily inhibited in any habitat, despite reduction in the density of immatures observed in intervention area in comparison to control

TDS: total dissolve solids; COD: Chemical Oxygen Demand

MECHANICAL/PHYSICAL CONTROL MEASURES

One report published in 2013 described a program undertaken by the Health Department of Kolkata Municipal Corporation from November 2010 to April 2012.[52] They used plying speedboats along two long sewerage canals heavily infested with larvae, pupae and egg rafts of the Culex quinquefasciatus as a strategy to prevent breeding. Stretches of canal too shallow to permit the use of speedboats were treated with a larvicidal spray, temephos 50% emulsifiable concentrate, using small rowing boats as transport.

SUMMARY OF THE MAIN FINDINGS

The city observed a dramatic decline (>95%) in the densities of egg rafts, immatures, and adult insects when the speedboats were deployed and remained low for the duration of the project. The Municipal Corporation spent an estimated USD 33.8 per km per day on speedboat hire and USD 170.4 per km per day on the administration of larvicide. The authors argued that the cost was comparable to that of using larvicidal spray where this required the use of rowing boats.[52]

Although believed to be an eco-friendly intervention, there were concerns around potential air pollution from combustion of fuels used to power the speedboats, noise pollution and other possible effects on the canal ecosystem. Also, long-term epidemiological outcomes were not reported potentially because the burden of lymphatic filariasis at the time of the study was minimal in this city.

ENVIRONMENTAL CONTROL MEASURES

Two reports examined the effect of different housing structures as a vector control strategy. One was a Phase III study conducted in 2000 in Uttar Pradesh[53] and the second was a Phase II study conducted in 2004 in Andhra Pradesh.[54] In both reports the effect of well-constructed houses with concrete walls, cement floors, adequate ventilation and lighting was compared to moderate and poorly constructed houses with unplastered or mud plastered walls, tiled roofs, mud plastered floors, inadequate ventilation and low light.

SUMMARY OF THE MAIN FINDINGS

Significant differences in vector density, infection rate, infectivity rate, and microfilaria prevalence were observed between the different housing structures despite seasonal variation in month-wise per man hour density (PMHD). The PMHD, infection, and infectivity rates of Culex quinquefasciatus was lowest in the well-constructed houses and highest in the poorly constructed houses. There was a 12.2% microfilariae rate and 6.7% disease rate among the residents of poorly constructed houses compared to 5.8% microfilariae rate and 2.9% disease rate among residents of moderately constructed houses and a 0% microfilariae rate and 2.7% disease rate among residents of well-constructed houses.[53]

The implementation of this type of intervention will require highly coordinated intersectoral collaboration, financial planning, and community support. Implementation will need to happen over many years and will require careful planning and adequate resources as it involves the construction of new houses or restructuring of old ones.

CHEMICAL CONTROL MEASURES

Thirty-three reports described the use of chemical control measures. Interventions included growth regulators, residual spraying, chemical insecticides, long-lasting insecticidal nets, traditional nets, personal repellents, insecticide impregnated net and insecticide impregnated curtains.

GROWTH REGULATORS

Four reports published between 2005 and 2012 reported on the use of growth regulators to control LF vectors.[55–58] All included studies were Phase II studies. The studies were conducted in Delhi,[55] Tamil Nadu,[56] Puducherry[57] and multiple states (Haryana and Delhi).[58] Growth regulators assessed were: triflumuron, pyriproxyfen and diflubenzuron.

SUMMARY OF THE MAIN FINDINGS

Triflumuron resulted in 100% inhibition of Culex quinquefasciatus in different types of habitats for 3-7 weeks even at a low dose of 0.5 parts per million. Pyriproxyfen at 0.5 kg active ingredient needed per hectare/acre resulted in >80% emergence inhibition of adult mosquitoes for 4 weeks in drains with slow moving water. In stagnant drains, cesspits and disused wells, doses as small as 0.1 kg active ingredient needed per hectare/acre yielded >80% emergence inhibition and the effect increased with higher doses. The efficacy of Diflubenzuron varied with the formulation used and the habitats where it was tested. The wettable powder and granular formulations yielded >80% inhibition of adult emergence for 7-10 days in cesspits, 4-7 days in street drains and 7-21 days in abandoned wells at all dosages tested. When the 25% wettable powder and 22% semiliquid were compared, both formulations were highly effective and showed almost similar effects when applied in the field at doses of 0.004 and 0.008 g/m^2 in their respective preferential breeding habitats. Standard doses of the tablet formulation were inefficient in polluted larval habitats.

MOSQUITO REPELLENTS/ATTRACTANTS

Nine records published between 1991 and 20011 describe the effect of personal repellents on mosquitoes.[59–67] Interventions described were; Neem oil,[59,62,65,67] Neem cream,[66] Pine oil,[61] N, N-Diethyl-meta-toluamide (DEET)-permethrin soap, [64] DEET impregnated anklets, wristbands, shoulder and pocket fabric strips,[60] and advanced Odomos cream.[63] The studies were conducted in Uttar Pradesh, Gujarat, and Tamil Nadu.

Two records described the use of mosquito attractants as vector control strategy.[68,69] Sukumaran et al. used optimized Biogenic Carbon Dioxide produced by yeast as a mosquito attractant.[68] Suman et al, used a plant-based commercial-grade formulation containing rabbit chow, developed for the trap "the mosquito preventer".[69]

SUMMARY OF THE MAIN FINDINGS

Pine oil and Pine mats provided 97% and 88% protection against Culex quinquefasciatus for nine and 7 hours, respectively. Neem oil provided >75% protection from Culex quinquefasciatus with concentrations of 2% and above. The effect seems to be dose dependent, with higher concentrations of 50% and 100% yielding even better results. The use of DEET-permethrin soap resulted in 89% to 100% reduction in man-vector contact for eight mosquito species, including Culex quinquefasciatus. DEET-impregnated anklets, wristbands, shoulder, and pocket fabric strips at a concentration of 2 mg/cm^2 provided 5 hours of complete protection against mosquito bites and the reduction of man-landing rate varied between 65.85 and 100%. Lower concentrations yielded less suitable results. 10 mg/cm^2 of advanced Odomos cream yielded 98.8 % against Culex quinquefasciatus for up to 9 hours. Neem and pine oils are indigenous, easily available at low cost, and generally acceptable to the village communities.

When used along with mosquito traps, biogenic carbon dioxide increased the trapping efficiency for Culex quinquefasciatus 6.48-fold in one of the traps when compared to traps without biogenic CO2. Traps containing the plant-based commercial-grade formulation collected 1.27-fold more larvae than the control. The oviposition attraction index was estimated at 0.7 in the first week with the attractancy lasting over two weeks.[69]

RESIDUAL SPRAYING

Five reports published between 1989 and 2004 examined the effect of residual spraying.[70–74] Two of the studies were conducted in Uttar Pradesh, one in Madhya Pradesh, one in Karnataka and a multistate study in Maharashtra and Gujarat. The full text was only available for one study which was a Phase III study. The chemicals used for residual spraying were reldan, deltamethrin, clothianidin and cyfluthrin. Four rounds of indoor residual spraying were carried out on mud walls, cement walls and brick walls using reldan 40% emulsifiable concentrate at 0.5 g/m^2 and 1 g/m^2 from 1999-2000.[70] Deltamethrin 2.5% wettable powder was used for five rounds of residual spraying in one study,[71] and for one round in another study.[72] For the last study conducted in Karnataka, spraying was done using Clothianidin, 300 mg active ingredient/m^2; deltamethrin, 25 mg active ingredient/m^2; bendiocarb, 400 mg active ingredient/m^2; and pirimiphos-methyl, 1g active ingredient/m^2.

SUMMARY OF THE MAIN FINDINGS

Use of reldan resulted in substantial reduction of total mosquito density in the experimental village as compared to the control village, with 100% mortality of Culex quinquefasciatus at 0.5 g/m2 and 1 g/m2 doses. The residual effect lasted over eight to ten weeks and decreasing thereafter. Deltamethrin was also found to be effective in reducing the mosquito populations, with the duration of the residual effect ranging between 10 to 16 weeks. Although two of the reports presented epidemiological endpoints for malaria, none of them reported on the impact of the intervention on lymphatic filariasis. Clothianidin was less effective in reducing mean mosquito density per room when compared to bendiocarb, pirimiphos-methyl and deltamethrin.[73]

INSECTICIDE IMPREGNATED CURTAINS

Two reports published in 2001[75] and 2009[76] described the use of deltamethrin treated curtains and Insecticide incorporated plastic sheeting (ZeroFly) respectively for vector control.

SUMMARY OF THE MAIN FINDINGS

The entry rate of Culex quinquefasciatus decreased when the preintervention period was compared to the post intervention period by 68% among houses that used ZeroFly plastic sheets. It doubled in the houses with untreated plastic sheets and tripled in the houses with no plastic sheet.[76] Deltamethrin-treated curtains were shown to significantly reduce the indoor resting density of Culex quinquefasciatus by 82.6% after the first impregnation and by 91.7% after the second impregnation. The overall reduction however was more pronounced for Anopheles and Aedes species than for Culex quinquefasciatus.

INSECTICIDE IMPREGNATED NETS

Five reports published between 2000 and 2009 described the assessment of the effects of deltamethrin impregnated nets using Phase II studies.[77–80] These nets were compared to use of untreated or no nets in two reports;[77,78] etofenprox nets, cyfluthrin nets , lambda cyhalothrin nets or untreated nets in one report;[79] and untreated nets, indoor spraying with DDT, and no nets in one study.[80]

SUMMARY OF THE MAIN FINDINGS

Deltamethrin-impregnated mosquito nets were not efficient against Culex quinquefasciatus. Two reports describe a 49.7% decrease in the density of Culex quinquefasciatus,[77,78] while in one report, Culex quinquefasciatus resting in village houses, those in exit traps and those dead on floor sheets did not show a reduction in numbers or significant difference when treated nets where compared with untreated or no nets. Mortality was delayed for Culex quinquefasciatus.[80] When the effect of mosquito nets impregnated with other insecticides such as etofenprox, cyfluthrin, lambda cyhalothrin were compared to deltamethrin, their repellent effects though being similar across compounds were more pronounced on anopheles mosquitoes compared to Culex quinquefasciatus. There was significant difference between the repellant and excito-repellant effects of deltamethrin and etofenprox against Culex quinquefasciatus. [75] The corrected mortality for landing female Culex quinquefasciatus was greatest for etofenprox although it remained low. Regarding the number of female mosquitoes landing on human volunteers sleeping under partially lifted nets deltamethrin produced 89.1% protection, while lambda cyhalothrin, etofenprox and cyfluthrin provided 90.6, 93.7 and 96.1% protection, respectively.[75]

LONG-LASTING INSECTICIDAL NETS

Four reports published between 2006 and 2012 describe the effects of Long-lasting insecticidal nets on Culex quinquefasciatus. The nets were coated with alpha-cypermethrin (Interceptor) in two reports,[81,82] and had permethrin incorporated within their fibers (Olyset) in the other two reports.[83,84]

SUMMARY OF THE MAIN FINDINGS

The use of long-lasting insecticide nets as a vector control tool against Culex quinquefasciatus had mixed results. In the pre-intervention period, the entry rate of Culex quinquefasciatus was 2.0 in interceptor houses, 2.3 in control houses having untreated nets and 2.7 in houses without mosquito nets. During the intervention phase the entry rate reduced to 0.6 in interceptor village while it increased in the villages with untreated or no nets.[82] When Olyset nets were used, the mean entry rate increased from 1.8 in the preintervention period to 2.6 in the intervention period.

The proportion of blood fed female Culex quinquefasciatus significantly reduced in the areas using interceptor and Olyset nets when the pre-intervention period was compared to the intervention period. It was also significantly lower in the homes that had these nets than in homes without nets or those using untreated nets.[81,82] The immediate and delayed mortality for Culex quinquefasciatus in interceptor villages were 25.7% and 71.5% respectively, compared to just over 1% for both villages without nets and those using untreated nets. Use of Olyset nets resulted in higher mortality rates, as there was 100% mortality observed after 24 hours.[83]

CHEMICAL INSECTICIDES

Three reports published between 1997 and 2019 describe the effects of various chemical insecticides on Culex quinquefasciatus including neem oil, fenthion, and pirimiphos-methyl. [85–87]

SUMMARY OF THE MAIN FINDINGS

Neem oil applied at a rate of 140 mg active ingredient/m^2 was effective in reducing larvae of Culex quinquefasciatus by 95.5% on day 1, and thereafter 80% reduction was achieved for up to 3 weeks. Fenthion was equally effective, with doses of 2.5 resulting in larval mortality of more than 95% for 14 weeks and 80-95% from 15 to 25th week of fourth instar larvae of Mansonia annulifera. Pirimiphos-methyl was found to be most effective against larvae of Anopheles stephensi than Culex quinquefasciatus for which higher doses were required.[85]

Overall, chemical measures are effective against Culex quinquefasciatus. However most of the identified records present epidemiological endpoints for Malaria without presenting these endpoints for LF. LF and Malaria vector control need to be integrated and evidence around the effects of chemical measures in LF control that are not covered by the malaria program should be identified and listed as priority research areas.

OTHER INTERVENTIONS

There were six records that described interventions which did not fit into any of the five main categories of vector control strategies proposed in the WHO framework.

Data mining

In a project sponsored by the Ministry of Communication and Information Technology, Kumar et al. successfully demonstrate the applicability of using classification and regression trees (CART) to predict and forecast mosquito density during different months of a year in the region.[88] Interventions such as this one can play an important role in the surveillance of vector populations.

Nanoparticles

Two reports describe the use of nanoparticles in vector control.[89,90] Gold[90] and silver[89] nanoparticles synthesized using plant extracts as reducing and stabilizing agents led to 100% larval mortality after 72 hours and a significant boost in the predation efficiency of larvivorous fish when tested in aquatic environment.[89,90] These are innovative interventions whose effectiveness should be further investigated using larger studies.

In one report, no intervention was tested. However, the authors examined the association between the reported usage of personal-protection measures against mosquitoes and the prevalence of Wuchereria bancrofti.[91] They found that 75%–92% of households used at least one type of personal-protection measure against mosquitoes. This resulted among other factors to a decrease in the prevalence of Wuchereria bancrofti microfilaremia to just 1%.

COMMUNITY OWNERSHIP

Attempts to encourage community ownership of vector control measures are described in all four integrated vector control projects mentioned earlier in this report. Communities were engaged mostly through community education using various media to educate the public on the dangers of unsanitary conditions. This is insufficient if the objective is to enable community ownership of vector control initiatives. Two projects: The FILCO movement and the Tamil Nadu projects (MDA vs MDA+ integrated vector control) successfully motivated the communities to take over and lead the vector control measures. We have provided details about how the researchers were able to move from community engagement to ownership as lessons learned under the FILCO movement.

A report by Nandha et al. specifically describes the use of community based education campaign as a vector control tool in Tamil Nadu.[92] Intensive educational classes were conducted by social scientist in four schools and reinforced by teachers fortnightly for a period of 8 months. Students then educated their community members at fortnightly intervals on vector control measures through elimination of breeding sites and the use of personal protection measures to prevent mosquito bites. Trained members of 23 Women Self Help Groups also worked with the research team to educate their communities. No insecticide application was used, and vector control was based on actions initiated following educational intervention. Knowledge on the transmission, and prevention of filariasis doubled in the intervention village and did not change in the control village. The intervention also resulted in community members taking more actions towards mosquito control breeding sites leading to a significant reduction in per man-hour indoor resting density of mosquitoes being observed in the intervention area. The per capita cost for reducing 87% of mosquito density with this intervention was estimated at USD 0.32.

Communities should be involved in the fight against lymphatic filariasis. Community involvement spans across a spectrum from marginalization to ownership (Table 6) hence the LF Program should define a priori what they anticipate the role of the community to be as this will inform the community engagement goals, messaging, activities and resource allocation.[93] Evidence on enablers and barriers to community ownership of vector control interventions is needed.

Table 5: The spectrum of community engagement to ownership

	IGNORE	INFORM	CONSULT	INVOLVE	COLLABORATE	DEFER TO
IMPACT	Marginalization	Placation	Tokenization	Voice	Delegated power	Community ownership
MESSAGE TO COMMUNITY	Deny access to decision-making processes	Provide the community with relevant information	Gather input from the community	Ensure community needs and assets are integrated into process & inform planning	Ensure community capacity to play a leadership role in implementation of decisions	Foster democratic participation and equity through community driven decision making; Bridge divide between community & governance
ACTIVITIES	Closed door meeting Misinformation Systematic	Fact sheets Open Houses Presentations Billboards Videos	Public Comment Focus Groups Community Forums Surveys	Community organizing & advocacy House meetings Interactive workshops Polling Community forums	MOU's with Community-based organizations Community organizing Citizen advisory committees Open Planning Forums with Citizen Polling	Community-driven planning Consensus building Participatory action research Participatory budgeting Cooperatives
RESOURCES ALLOCATION RATIO	100% Systems Admin	70-90% Systems Admin 10-30% Promotions and Publicity	60-80% Systems Admin 20-40% Consultation Activities	50-60% Systems Admin 40-50% Community Involvement	20-50% Systems Admin 50-70% Community Partners	80-100% Community partners and community-driven processes ideally generate new value and resources that can be invested in solutions

Source: Adapted from the Spectrum of Community Engagement to Ownership[93]

Conclusion

Although our search strategy was quite broad, we cannot exclude the possibility that we may have missed some country level reports as we did not search grey literature. Also, out of the 83 relevant reports identified by our systematic search, we were able to obtain the full texts of only 62 reports. Over 90% (19/21) of the reports without full texts were published before the year 2000. We may have missed out important information from reports whose full texts could not be accessed. However, these reports were probably published in smaller or local journals and may not represent the most robust evidence for a specific vector control measure. Our review may also not be able to identify important contextual considerations and should be interviews with stakeholders and communities are recommended to provide more depth.

Vector control initiatives tested or implemented so far by the Indian government, LF elimination program, researchers and communities are highly commendable and continued efforts are encouraged. Renewed political commitment, intra- and inter-sectoral collaborations and capacity strengthening of vector control staff within the LF program will be critical as India makes giant steps to win the race against LF.

Appendix

Table 6: Search strategies for PubMed, Embase and Central

SEARCH ENGINE	SEARCH DETAILS	RESULTS
PubMed	((((((("india"[MeSH Terms] OR "india"[All Fields]) OR "india s"[All Fields]) OR "indias"[All Fields]) OR "Bharat"[All Fields]) OR "Hindustan"[All Fields]) AND (((((((((((((((((("genetic vectors"[MeSH Terms] OR ("genetic"[All Fields] AND "vectors"[All Fields])) OR "genetic vectors"[All Fields]) OR "vector"[All Fields]) OR "disease vectors"[MeSH Terms]) OR ("disease"[All Fields] AND "vectors"[All Fields])) OR "disease vectors"[All Fields]) OR "vectors"[All Fields]) OR "vector s"[All Fields]) OR "vectored"[All Fields]) OR "vectoring"[All Fields]) OR "vectorization"[All Fields]) OR "vectorize"[All Fields]) OR "vectorized"[All Fields]) OR "vectorizing"[All Fields]) OR (((((("culicidae"[MeSH Terms] OR "culicidae"[All Fields]) OR "mosquito"[All Fields]) OR "mosquitoe"[All Fields]) OR "mosquitoes"[All Fields]) OR "mosquitos"[All Fields]) OR "mosquito s"[All Fields])) OR ("aedes"[MeSH Terms] OR "aedes"[All Fields])) OR ("culex"[MeSH Terms] OR "culex"[All Fields])) OR (("anophele"[All Fields] OR "anopheles"[MeSH Terms]) OR "anopheles"[All Fields])) OR (("malvaceae"[MeSH Terms] OR "malvaceae"[All Fields]) OR "mansonia"[All Fields]))) AND ((((((("control*"[All Fields] OR "eliminat*"[All Fields]) OR "eradicat*"[All Fields]) OR "larvici*"[All Fields]) OR "interrupt*"[All Fields]) OR ((((((("destruct"[All Fields] OR "destructed"[All Fields]) OR "destructing"[All Fields]) OR "destruction"[All Fields]) OR "destructions"[All Fields]) OR "destructive"[All Fields]) OR "destructively"[All Fields]) OR "destructs"[All Fields])) OR (((((((((((((("manage"[All Fields] OR "managed"[All Fields]) OR "management s"[All Fields]) OR "managements"[All Fields]) OR "manager"[All Fields]) OR "manager s"[All Fields]) OR "managers"[All Fields]) OR "manages"[All Fields]) OR "managing"[All Fields]) OR "managment"[All Fields]) OR "organization and administration"[MeSH Terms]) OR ("organization"[All Fields] AND "administration"[All Fields])) OR "organization and administration"[All Fields]) OR "management"[All Fields]) OR "disease management"[MeSH Terms]) OR ("disease"[All Fields] AND "management"[All Fields])) OR "disease management"[All Fields])) OR "IVM"[All Fields])) AND (("filariasis"[MeSH Terms] OR "filariasis"[All Fields]) OR "filariases"[All Fields])	503
Embase	(India OR Bharat OR Hindustan) AND (vector OR mosquito OR aedes OR culex OR anopheles OR mansonia) AND (control* OR eliminat* OR eradicat* OR larvici* OR interrupt* OR destruction OR management OR ivm) AND filariasis	703
CENTRAL	(India OR Bharat OR Hindustan) AND (Vector OR Mosquito OR Aedes OR Culex OR Anopheles OR Mansonia) AND (Control* OR Eliminat* OR Eradicat* OR Larvici* OR Interrupt* OR Destruction OR Management OR IVM) AND (Filariasis) (Word variations have been searched)	23

References

1. Handbook for Integrated Vector Management in the Americas; 2019 - PAHO/WHO | Pan American Health Organization [Internet]. [cited 2020 Feb 20]. Available from: https://www.paho.org/en/documents/handbook-integrated-vector-management-americas-2019

2. Lymphatic filariasis : Epidemiology, Treatment and Prevention -- the Indian Perspective. 2018.

3. WHO | Handbook for integrated vector management. World Health Organization; 2016.

4. WHO | Global vector control response 2017–2030. World Health Organization; 2018.

5. World Health Organisation (WHO). lymphatic Filariasis: Global Programme to Eliminate Lymphatic Filarariasis. 2013.

6. Arksey H, O'Malley L. Scoping studies: towards a methodological framework. Int J Soc Res Methodol. 2005 Feb;8(1):19–32.

7. Peters MDJ, Godfrey CM, Khalil H, McInerney P, Parker D, Soares CB. Guidance for conducting systematic scoping reviews. Int J Evid Based Healthc. 2015 Sep 1;13(3):141–6.

8. Handbook for Integrated Vector Management in the Americas; 2019 - PAHO/WHO | Pan American Health Organization [Internet]. [cited 2020 Sep 5]. Available from: https://www.paho.org/en/documents/handbook-integrated-vector-management-americas-2019

9. Sabesan S, Vanamail P, Raju K., Raju P. Lymphatic filariasis in India: Epidemiology and control measures. J Postgrad Med. 2010;56(3):232.

10. Elimination of Lymphatic Filariasis: National Vector Borne Disease Control Programme (NVBDCP) [Internet]. [cited 2020 Sep 6]. Available from: https://nvbdcp.gov.in/index4.php?lang=1&level=0&linkid=461&lid=3739

11. Sharma GK, Rao CK, Sharma SP, Sundaram RM, Ghosh TK, Raina VK, et al. Relative impact of integrated vector control strategy vis-a-vis conventional control strategy on bancroftian filariasis in Pondicherry. J Commun Dis. 1986 Dec 1;18(4):267–75.

12. Rajagopalan PK, Panicker KN, Pani SP. Impact of 50 years of vector control on the prevalence of Brugia malayi in Shertallai area of Kerala state. Indian J Med Res. 1989;89(11).

13. Das PK, Manoharan A, Subramanian S, Ramaiah KD, Pani SP, Rajavel AR, et al. Bancroftian filariasis in Pondicherry, South India – epidemiological impact of recovery of the vector population. Epidemiol Infect. 1992;108(3):483–93.

14. Rajagopalan PK, Das PK, Subramanian S, Vanamail P, Ramaiah KD. Bancroftian filariasis in Pondicherry, South India: 1. Pre-control epidemiological observations. Epidemiol Infect. 1989;103(3):685–92.

15. Subramanian S, Pani SP, Das PK, Rajagopalan PK. Bancroftian filariasis in Pondicherry, South India: 2. Epidemiological evaluation of the effect of vector control. Epidemiol Infect. 1989;103(3):693–702.

16. Ramaiah KD, Das PK, Arunachalam N, Rajavel AR, Paily KP. Observations on population density of Culex quinquefasciatus and transmission indices of Bancroftian filariasis during and after Integrated Vector Management strategy. J Commun Dis. 1992 Sep 1;24(3):173–84.

17. Rajagopalan PK, Das PK, Pani SP, Mariappan T, Rajavel AR, Ramaiah KD, et al. Evaluation of

integrated vector control measures on filariasis transmission in Pondicherry. Indian J Med Res. 1988 May 1;87:434–9.

18. Ramaiah KD, Das PK, Dhanda V. Estimation of permissible levels of transmission of bancroftian filariasis based on some entomological and parasitological results of a 5-year vector control programme. Acta Trop. 1994 Feb 1;56(1):89–96.

19. Rajagopalan PK, Panicker KN, Das PK. Control of malaria and filariasis vectors in South India. Vol. 3, Parasitology Today. 1987. p. 233–41.

20. Sunish IP, Rajendran R, Mani TR, Munirathinam A, Tewari SC, Hiriyan J, et al. Resurgence in filarial transmission after withdrawal of mass drug administration and the relationship between antigenaemia and microfilaraemia - a longitudinal study. Trop Med Int Heal. 2002 Jan 1;7(1):59–69.

21. Sunish IP, Rajendran R, Mani TR, Munirathinam A, Dashb AP, Tyagi BK. Vector control complements mass drug administration against bancroftian filariasis in Tirukoilur, India. Bull World Health Organ. 2007 Feb;85(2):138–45.

22. Curtis CF, Malecela-Lazaro M, Reuben R, Maxwell CA. Use of floating layers of polystyrene beads to control populations of the filaria vector Culex quinquefasciatus. Ann Trop Med Parasitol. 2002;96 Suppl 2.

23. Reuben R, Rajendran R, Sunish IP, Mani TR, Tewari SC, Hiriyan J, et al. Annual single-dose diethylcarbamazine plus ivermectin for control of bancroftian filariasis: Comparative efficacy with and without vector control. Ann Trop Med Parasitol. 2001;95(4):361–78.

24. Sunish IP, Kalimuthu M, Kumar VA, Munirathinam A, Nagaraj J, Tyagi BK, et al. Can community-based integrated vector control hasten the process of LF elimination? Parasitol Res. 2016 Jun 1;115(6):2353–62.

25. Dua VK, Sharma ISK, Srivastava' And A, Sharma' VP. Bioenvironmental control of industrial malaria at Bharat heavy electricals ltd., hardwar. India - results of a nine-year study (1987-95). J Am Mosq Control Assoc. 13(3).

26. Panicker KN, Dhanda V. Community participation in the control of filariasis - PubMed. World Health Forum. 1992;

27. Rajagopalan PK. An Entomologist's Adventures in Biomedical Research. J Commun Dis. 2019;51(3):62–76.

28. People play key role in anti-filaria project [Internet]. [cited 2020 Sep 7]. Available from: https://www.downtoearth.org.in/coverage/people-play-key-role-in-antifilaria-project-30598

29. Panicker KN, Dhanda V. Undesirable weeds.

30. Mohanty SS, Prakash S. Laboratory and field evaluation of the fungus Chrysosporium lobatum against the larvae of the mosquito Culex quinquefasciatus. Parasitol Res. 2008 Apr;102(5):881–6.

31. Kar I, Eapen A, Ravindran KJ, Chandrahas RK, Appavoo NC, Sadanand A V., et al. Field Evaluation of Bacillus sphaericus, H5a5b and B. thuringiensis var. israelensis, H-14 against the Bancroftian filariasis Vector Culex quinquefasciatus, Say in Chennai, India. Indian J Malariol. 1997 Mar 1;34(1):25–36.

32. Yadav RS, Sharma VP, Upadhyay AK. Field trial of Bacillus sphaericus strain B-101 (serotype H5a, 5b) against filariasis and Japanese encephalitis vectors in India. J Am Mosq Control Assoc. 1997;13(2):158–63.

33. Ansari MA, Sharma VP, Mittal PK, Razdan RK. Efficacy of two flowable formulations of Bacillus sphaericus against larvae of mosquitoes. Indian J Malariol. 1995;32(2):76–84.

34. Mittal PK, Adak T, Batra CP, Sharma VP. Laboratory and field evaluation of Spherix, a formulation of Bacillus sphaericus (B-101), to control breeding of Anopheles stephensi and Culex quinquefasciatus. Indian J Malariol. 1993;30(2):81–9.

35. Sharma SN, Sharma T, Prasad H. Impact of Spherix (Bacillus sphaericus B-101, Serotype H5a, 5b) spraying on the control of mosquito breeding in rural areas of Farrukhabad District, Uttar Pradesh. Indian J Malariol. 1998;35(4):185–96.

36. Srivastava R, Tilak V, Mukherjee S, Yadav J. Field trial of Bacillus Thuringiensis var Israelensis pellet formulation in the control of mosquitoes. Med J Armed Forces India. 1996 Oct;52(4):233–5.

37. Tamilselvan S, Jambulingam P, Manoharan V, Shanmugasundaram R, Vivekanandan G, Manonmani AM. Fly ash based Bacillus thuringiensis var. Israelensis formulation for use against Culex quinquefasciatus, the vector of filariasis in natural ecosystems. J Vector Borne Dis. 2015;52(3):193–200.

38. Haq S, Bhatt RM, Vaishnav KG, Yadav RS. Field evaluation of biolarvicides in Surat City, India. J Vector Borne Dis. 2004;41(3–4):61–6.

39. Sharma SK, Upadhyay AK, Haque MA, Raghavendra K, Dash AP. Field evaluation of a previously untested strain of biolarvicide (Bacillus thuringiensis israelensis H14) for mosquito control in an urban area of Orissa, India. J Am Mosq Control Assoc. 2008 Sep;24(3):410–4.

40. Uragayala S, Kamaraju R, Tiwari S, Ghosh SK, Valecha N. Field testing & evaluation of the efficacy & duration of effectiveness of a biolarvicide, Bactivec® SC (Bacillus thuringiensis var. israelensis SH-14) in Bengaluru, India. Indian J Med Res. 2018 Mar 1;147(March):299–307.

41. Dua VK, Sharma SK, Sharma VP. Application of bactoculicide (Bacillus thuringiensis H-14) for controlling mosquito breeding in industrial scrap at BHEL, Hardwar (U.P.). Indian J Malariol. 1993;30(1):17–21.

42. Sharma SN, Shukla RP, Mittal PK, Adak T, Kumar A. Efficacy of a new formulation of bacillus thuringiensis var israelensis (Bti) in laboratory and field conditions of Kumaun foothills of Uttaranchal, India. J Commun Dis. 2003;35(4):290–9.

43. Sadanandane C, Gunasekaran K, Boopathi Doss PS, Jambulingam P. Field evaluation of the biolarvicide, spinosad 20 per cent emulsifiable concentrate in comparison to its 12 per cent suspension concentrate formulation against culex quinquefasciatus, the vector of bancroftian filariasis in India. Indian J Med Res. 2018 Jan 1;147(January):32–40.

44. Panicker KN, Jayasree M, Krishnamoorthy K. A cost benefit analysis of fish culture strategy towards the control of mansonioides in Shertallai, Kerala state. Indian J Med Res - Sect A Infect Dis. 1992;95(MAY.):157–60.

45. Dua VK, Pandey AC, Rai S, Dash AP. Larvivorous activity of Poecilia reticulata against Culex quinquefasciatus larvae in a polluted water drain in Hardwar, India. J Am Mosq Control Assoc. 2007 Dec;23(4):481–3.

46. Gupta DK, Bhatt RM, Sharma RC, Gautam AS, Rajnikant. Intradomestic mosquito breeding sources and their management. Indian J Malariol. 1992;29(1):41–6.

47. Prasad H, Prasad RN, Haq S. Control of mosquito breeding through Gambusia affinis in rice fields. Indian J Malariol. 1993;30(2):57–65.

48. Das MK, Rajesh Kumar Rao M, Kulsreshtha AK. Native larvivorous fish diversity as a biological

control agent against mosquito larvae in an endemic malarious region of Ranchi district in Jharkhand, India. J Vector Borne Dis. 2018 Mar 1;55(1):34–41.

49. Jayasree M, Sabesan S, Panicker KN. Weedivorous fishes for the control of vectors of Malayan filariasis. Indian J Med Res - Sect A Infect Dis. 1990;91(SEPT.):379–81.

50. Jayasree M, Sabesan S, Kuriakose KM, Panicker KN. Giant gourami (Osphronemus goramy: Anabantoidei) as a potential agent for control of weeds, the breeding source for the vectors of Brugia malayi. Indian J Med Res. 1989;89:110–3.

51. Ansari MA, Sharma VP. Role of Azolla in controlling mosquito breeding in Ghaziabad district villages (U.P.). Indian J Malariol. 1991;28(1):51–4.

52. Biswas D, Mandal B, Biswas B, Banerjee A, Mukherjee TK. Plying of speedboats along canals in the city of kolkata, india, to prevent mosquito breeding. Trans R Soc Trop Med Hyg. 2013 Mar;107(3):147–51.

53. Baruah K, Rai RN. The impact of housing structures on filarial infection. Jpn J Infect Dis. 2000;53(3):107–10.

54. Satya Kumar DVR, Krishna D, Suryanarayana Murty U, Sai KSK. Impact of different housing structures on filarial transmission in rural areas of southern India. Southeast Asian J Trop Med Public Health. 2004;35(3):587–90.

55. Ansari MA, Razdan RK, Sreehari U. Laboratory and field evaluation of Hilmilin against mosquitoes. J Am Mosq Control Assoc. 2005 Dec;21(4):432–6.

56. Sadanandane C, Boopathi Doss PS, Jambulingam P. Efficacy of three formulations of diflubenzuron, an insect growth regulator, against culex quinquefasciatus say, the vector of bancroftian filariasis in india. Indian J Med Res. 2012 Nov;136(5):783–91.

57. Jambulingam P, Sadanandane C, Boopathi Doss PS, Subramanian S, Zaim M. Field evaluation of an insect growth regulator, pyriproxyfen 0.5% GR against Culex quinquefasciatus, the vector of Bancroftian filariasis in Pondicherry, India. Acta Trop. 2008;107(1):20–4.

58. Batra CP, Mittal PK, Adak T, Ansari MA. Efficacy of IGR compound Starycide 480 SC (Triflumuron) against mosquito larvae in clear and polluted water. J Vector Borne Dis. 2005;42(3):109–16.

59. Kant R, Pandey SD, Sharma SK. Role of biological agents for the control of mosquito breeding in rice fields. Indian J Malariol. 1996;33(4):209–15.

60. Karunamoorthi K, Sabesan S. Field trials on the efficacy of DEET-impregnated anklets, wristbands, shoulder, and pocket strips against mosquito vectors of disease. Parasitol Res. 2009 Sep;105(3):641–5.

61. Ansari MA, Mittal PK, Razdan RK, Sreehari U. Larvicidal and mosquito repellent activities of Pine (Pinus longifolia, Family: Pinaceae) oil. J Vector Borne Dis. 2005;42(3):95–9.

62. Mandal S. Repellent activity of eucalyptus and azadirachta indica seed oil against the filarial mosquito culex quinquefasciatus say (Diptera: Culicidae) in India. Asian Pac J Trop Biomed. 2011 Sep 1;1(SUPPL. 1):S109–12.

63. Mittal PK, Sreehari U, Razdan RK, Dash AP, Ansari MA. Effcacy of Advanced Odomos repellent cream (N, N-diethyl-benzamide) against mosquito vectors. Indian J Med Res. 2011;133(4):426–30.

64. Mani TR, Reuben R, Akiyama J. Field efficacy of “Mosbar” mosquito repellent soap against

vectors of bancroftian filariasis and Japanese encephalitis in southern India. J Am Mosq Control Assoc. 1991;7(4):565–8.

65. Ravindran J, Eapen A, Kar I. Evaluation of Repellent Action of Neem Oil against the Filarial Vector, Culex quinquefasciatus (Diptera: Culicidae). Indian J Malariol. 2002;39(1–2):13–7.

66. Dua VK, Nagpal BN, Sharma VP. Repellent action of neem cream against mosquitoes. Indian J Malariol. 1995;32(2):47–53.

67. Sharma SK, Dua VK, Sharma VP. Field studies on the mosquito repellent action of neem oil. Southeast Asian J Trop Med Public Health. 1995;26(1):180–2.

68. Sukumaran D, Ponmariappan S, Sharma AK, Jha HK, Wasu YH, Sharma AK. Application of biogenic carbon dioxide produced by yeast with different carbon sources for attraction of mosquitoes towards adult mosquito traps. Parasitol Res. 2016 Apr 1;115(4):1453–62.

69. Shankar Suman D. Evaluation of enhanced oviposition attractant formulations against Aedes and Culex vector mosquitoes in urban and semi-urban areas.

70. Ansari MA, Razdan RK. Impact of residual spraying of Reldan against Anopheles culicifacies in selected villages of District Ghaziabad (Uttar Pradesh), India. J Vector Borne Dis. 2004;41(3–4):54–60.

71. Gill KS, Rahman SJ, Panda R, Kumar K, Katyal R. Extended field trial of deltamethrin WDP for control of malaria at Jagdalpur, Madhya Pradesh, India. Indian J Malariol. 1997;34(4):173–87.

72. Singh K, Rahman SJ, Joshi GC. Village scale trial of deltamethrin against mosquitoes. J Commun Dis. 1989;21(4):339–53.

73. Sreehari U, Raghavendra K, Tiwari SN, Sreedharan S, Ghosh SK, Valecha N. Small-scale (Phase II) evaluation of the efficacy and residual activity of SumiShield® 50 WG (clothianidin 50%, w/w) for indoor residual spraying in comparison to deltamethrin, bendiocarb and pirimiphos-methyl for malaria vector control in Karnataka state. J Vector Borne Dis. 2018 Jun 1;55(2):122–9.

74. Yadava RL, Krishna Rao C, Biswas H. Field Trial of Cyfluthrin as an Effective and Safe Insecticide for Control of Malaria Vectors in Triple Insecticide Resistant Areas. J Commun Dis. 1996;28(4):287–98.

75. Ansari MA, Razdan RK. Concurrent control of mosquitoes and domestic pests by use of deltamethrin-treated curtains in the New Delhi Municipal Committee, India. J Am Mosq Control Assoc. 2001;17(2):131–6.

76. Sharma SK, Upadhyay AK, Haque MA, Tyagi PK, Mohanty SS, Mittal PK, et al. Field evaluation of ZeroFly® - An insecticide incorporated plastic sheeting against malaria vectors & its impact on malaria transmission in tribal area of northern Orissa. Indian J Med Res. 2009;130(4):458–66.

77. Deswal BS, Bhatnagar D, Tilak R, Basannar DR. Malaria control using deltamethrin impregnated bed nets in a cantonment area at Allahabad (U. P.). J Commun Dis. 2004;36(3):171–6.

78. Deswal BS, Bhatnagar D, Tilak R, Basannar DR. Malaria control using deltamethrin impregnated mosquito nets/insecticide treated bed nets: Experience in armed forces. J Commun Dis. 2005;37(4):297–300.

79. Ansari MA, Razdan RK. Relative Efficacy of Insecticide Treated Mosquito Nets (Diptera: Culicidae) Under Field Conditions. J Med Entomol. 2000 Jan 1;37(1):201–4.

80. Sharma SK, Upadhyay AK, Haque MA, Padhan K, Tyagi PK, Batra CP, et al. Village-scale evaluation of mosquito nets treated with a tablet formulation of deltamethrin against malaria

vectors. Med Vet Entomol. 2005 Sep;19(3):286–92.

81. Bhatt RM, Sharma SN, Uragayala S, Dash AP, Kamaraju R. Effectiveness and durability of Interceptor long-lasting insecticidal nets in a malaria endemic area of central India. Malar J. 2012;11.

82. Sharma SK, Upadhyay AK, Haque MA, Tyagi PK, Raghavendra K, Dash AP. Wash-resistance and field evaluation of alphacypermethrin treated long-lasting insecticidal net (Interceptor®) against malaria vectors Anopheles culicifacies and Anopheles fluviatilis in a tribal area of Orissa, India. Acta Trop. 2010 Oct 1;116(1):24–30.

83. Sharma SK, Upadhyay AK, Haque MA, Padhan K, Tyagi PK, Ansari MA, et al. Wash resistance and bioefficacy of Olyset net - A long-lasting insecticide-treated mosquito net against malaria vectors and nontarget household pests. J Med Entomol. 2006;43(5):884–8.

84. Sharma SK, Upadhyay AK, Haque MA, Tyagi PK, Mohanty SS, Raghavendra K, et al. Field evaluation of olyset nets: A long-lasting insecticidal net against malaria vectors anopheles culicifacies and anopheles fluviatilis in a hyperendemic tribal area of Orissa, India. J Med Entomol. 2009 Mar;46(2):342–50.

85. Ansaria MA, Mittal PK, Razdan RK, Dhiman RC, Kumar A. Evaluation of pirimiphos-methyl (50% EC) against the immatures of Anopheles stephensi/An. culicifacies (malaria vectors) and Culex quinquefasciatus (vector of bancroftian filariasis). J Vector Borne Dis. 2004;41(1–2):10–6.

86. Prasad MP, Rajendran G, Sabesan S, Kalyanasundaram M. Field evaluation of biodegradable controlled release formulation of fenthion against Mansonia mosquitos. Vol. 28, Southeast Asian Journal of Tropical Medicine and Public Health. 1997. p. 208–11.

87. Dua VK, Pandey AC, Raghavendra K, Gupta A, Sharma T, Dash AP. Larvicidal activity of neem oil (Azadirachta indica) formulation against mosquitoes. Malar J. 2009;8(1).

88. Kumar D, Sriram K, Rao KM, Murty US. Management of filariasis using prediction rules derived from data mining. Bioinformation. 2005 Feb 1;1(1):8–11.

89. Murugan K, Venus JSE, Panneerselvam C, Bedini S, Conti B, Nicoletti M, et al. Biosynthesis, mosquitocidal and antibacterial properties of Toddalia asiatica-synthesized silver nanoparticles: do they impact predation of guppy Poecilia reticulata against the filariasis mosquito Culex quinquefasciatus? Environ Sci Pollut Res. 2015 Nov 1;22(21):17053–64.

90. Subramaniam J, Murugan K, Panneerselvam C, Kovendan K, Madhiyazhagan P, Dinesh D, et al. Multipurpose effectiveness of Couroupita guianensis-synthesized gold nanoparticles: high antiplasmodial potential, field efficacy against malaria vectors and synergy with Aplocheilus lineatus predators. Environ Sci Pollut Res. 2016 Apr 1;23(8):7543–58.

91. Kumar KNV, Ramaiah KD. Usage of personal-protection measures against mosquitoes and the low prevalences of Wuchereria bancrofti microfilaraemia in the Indian city of Chennai. Ann Trop Med Parasitol. 2008 Jul;102(5):391–7.

92. Nandha B, Krishnamoorthy K. Impact of education campaign on community-based vector control in hastening the process of elimination of lymphatic filariasis in Tamil Nadu, South India. Health Educ Res. 2012 Aug 1;27(4):585–94.

93. González R. The Spectrum of Community Engagement to Ownership. 2019.