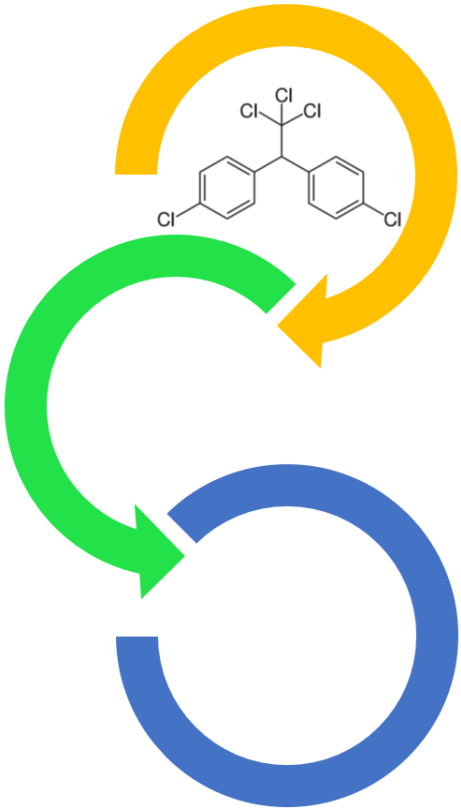
Stockholm Convention on Persistent Organic Pollutants (POPs)

Scientific and Technical Document Series: DDT

ROADMAP FOR DEVELOPING ALTERNATIVES TO DDT: LESSONS LEARNT FROM SRI LANKA



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I. INTRODUCTION

The Stockholm Convention aims to protect human health and the environment from Persistent Organic Pollutants (POPs)[1]. DDT is listed under the Convention with the acceptable purpose for production and use in disease vector control. The Convention furthermore stipulates that production and use of DDT for disease vector control must be in accordance with the World Health Organization recommendations and guidelines and when locally safe, effective and affordable alternatives are not available.

Hence, countries that are party to the Convention, and that continue to use DDT for disease vector control, are obliged to develop and adopt alternative products, methods and strategies aiming towards eliminating the use of DDT.

A roadmap has been established, at a request by the Conference of the Parties to the Stockholm Convention, for the development of alternatives to DDT [2], with a focus on strengthened country capacities for policy formulation, decision-making and implementation, and increased availability of chemical and non-chemical alternatives.

The objective of this document is to provide highlights of organizational structures and practices from the past 70 years in Sri Lanka in its path towards elimination of malaria. This is expected to produce good practices and lessons learnt, which will assist those countries still using DDT in their development and implementation of alternatives of DDT or local elimination of vector-borne disease.

Sri Lanka was selected for analysis, as a country that has eliminated the use of DDT for malaria control early on, while achieving gradual progress towards malaria control and, in 2012, having achieved elimination of malaria.

Sri Lanka is an island with dry, intermediate and wet climatic zones. Malaria was endemic in the dry and intermediate zones, where peak transmission occurred mostly during the rainy season. Conversely, in the wet zone, malaria occurred as epidemics during dry spells. The main malaria vector, *Anopheles culicifacies*, breeds in many types of clear and clean water bodies, but shallow pools in river beds are particularly important breeding habitats.

An overview of Sri Lanka road map for elimination of malaria

From 1946 until 2016, malaria vector control in Sri Lanka went through a number of phases (Figure 1). It started in 1946 with a full-fledged campaign of indoor residual spraying (IRS) using DDT. But after the vector developed resistance, the policy was changed from DDT to malathion and, subsequently, an evidence-based rotational scheme of insecticides was adopted. In the final phase, surveillance-based targeting of available interventions, including in addition to IRS, Insecticide Treated Nets (ITNs), and larviciding, led to malaria elimination.

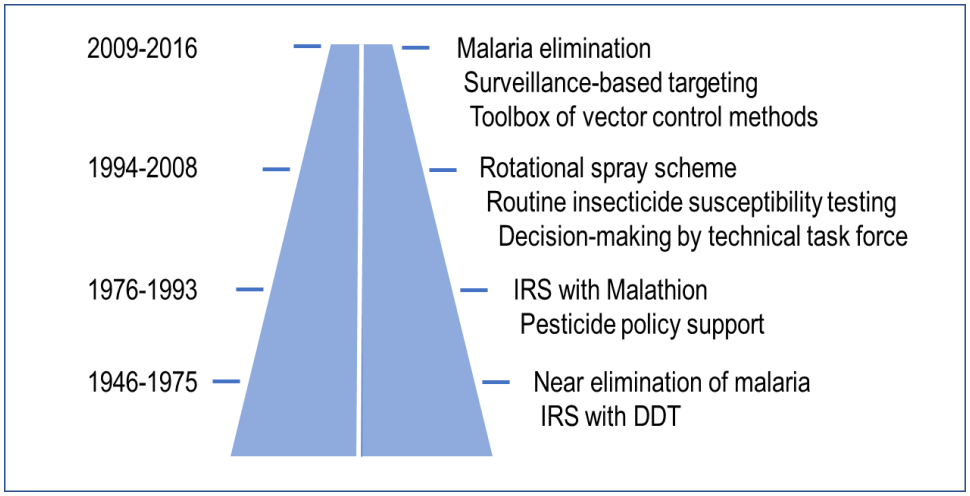

Figure 1. Periods and milestones along Sri Lanka's road towards achieving malaria elimination.

II. PERIOD 1. ATTEMPT TO ELIMINATE MALARIA WITH DDT (1946-1975)

1. Before World War II, larviciding and environmental modification of river streams were used to reduce vector breeding[3]. When in the year 1946, house spraying with DDT began, larval control was no longer deemed necessary.
2. DDT effectively controlled the vector mosquitoes resting on treated walls after a blood meal. Hence, house spraying was followed by a sharp reduction in malaria cases, which provided confidence that malaria transmission could be interrupted[4].
3. Following these advances in malaria control, Sri Lanka joined the global malaria eradication programme in 1956[5]. From 1958-1963, an 'attack phase' was implemented with substantial external support. During these five years, DDT spraying was intensive, and coverage was high.
4. At the end of the five year period, malaria incidence dropped from 1600 to just 17 cases in 1963. This was considered sufficient, and in 1964, the spraying campaign was completely withdrawn while case detection was emphasized.
5. But over the subsequent years, more malaria cases were being reported. New outbreaks started mostly in locations with slash-and-burn agricultural settlements, development projects and gem mining activities. This indicated that throughout the attack phase, the malaria parasite had persisted at these locations, where suitable vector breeding sites were abundant, and where people lived in temporary housing that could not be adequately sprayed. In the absence of vector control interventions, and facilitated by population movements, malaria readily spread from these foci to cause an island-wide resurgence among the human population in 1967-68[6].

6. DDT spraying was fully resumed in 1968, but this time around, malaria cases did not decline. Loss of acquired immunity had increased vulnerability of the human population, and householder acceptance of IRS had declined.
7. Moreover, DDT resistance was detected in 1969 at a number of locations (after previous tests in the 1960s had indicated DDT susceptibility)[7]. The findings set-off the alarm bells. Nevertheless, DDT continued to be used.
8. In 1973-75, a field study was conducted to determine whether reduced DDT susceptibility compromised malaria control. The outcomes indicated control failure of DDT. By 1976, DDT resistance had become widespread across the country.
9. At this time, the Government commissioned an independent programme evaluation. Following the evaluation's recommendation in 1976, a pivotal decision was made for total withdrawal of DDT, to be replaced with another insecticide[6]. That same year, Sri Lanka banned DDT from all uses, amidst growing concern about DDT's environmental effects.

III. PERIOD 2. POLICY CHANGE TO A DDT ALTERNATIVE (1976-1993)

1. After the independent recommendation to replace DDT, the organophosphate malathion was selected for IRS, to be used in a time-limited schedule -in anticipation of resistance development[8].
2. A field trial on the effectiveness of malathion demonstrated a marked reduction in local malaria incidence. Susceptibility tests confirmed that the main vector was fully susceptible to malathion.
3. To delay resistance development to malathion, the evaluation team recommended that this chemical should be used only in public health. In April 1976, a major decision was taken by the ministers of Health and Agriculture that import and use of malathion for agricultural purposes would be prohibited, and in 1985, legal status was given through the Malathion Control Act. A second insecticide, fenitrothion, was also banned from agriculture, to serve as 'back-up' in case malaria vectors developed resistance to malathion.
4. An intensive spraying campaign was implemented during 1977-82: the second attempt at eliminating malaria. Large quantities of malathion were applied, made possible by generous international support. At the end of the five years, malaria cases had dropped by 85% - but malaria elimination was still far out of reach.
5. Monitoring of resistance to malathion was conducted regularly, and was adopted as an integral program activity (not a research activity).
6. In 1982, the beginning signs of malathion resistance were detected[9]. Instead of switching to another insecticide, the programme decided to scale-down the intensity of spraying, as an attempt to delay resistance (and reduce costs). This was implemented

by replacing the blanket coverage spraying with more targeted spraying, whereby areas were stratified according to malaria risk and need-based applications of malathion made in each stratum.

7. Unfortunately, national malaria incidence did not decline but instead, increased further, reaching almost 700,000 cases in 1987. Newly developed and large-scale irrigation schemes in malaria-endemic zones lead to population movements from non-malarious zones. These settlers initially lived in temporary housing not adequately covered by IRS, while health infrastructure development was lagging behind. This was the second instance that agricultural developments disrupted the national efforts to control and eliminate malaria. Moreover, a civil conflict disrupted the control program in the North and East.
8. Another problem was that after the prolonged period of intensive IRS operations, refusal rates among householders increased while morale among spray teams sank. To make matters worse, malathion resistance became widespread by 1995.

IV. PERIOD 3. EVIDENCE-BASED ROTATION OF ALTERNATIVE INSECTICIDES (1994-2008)

1. After devolution of the public health sector in 1989, the implementation and logistics for malaria control were transferred to the provinces and districts. The decentralization improved the coordination of the program with general health services in the districts. Also, the shift towards local ownership reportedly benefited the morale among program staff, and made decision-making on malaria control more responsive and accountable. Training and technical leadership, which included procurement of insecticides, remained at national level.
2. When malathion resistance was reported from an increasing number of districts, it was recognized that alternatives were needed. In 1993-94, field testing in two districts using the pyrethroid lambda-cyhalothrin and the organophosphate fenitrothion for IRS indicated a promising decline in malaria incidence. Hence, these chemicals were added as insecticide options.
3. In 1994, the programme adopted WHO's global strategy on rotational use of unrelated insecticides for IRS, aiming to delay resistance development and to control malaria. Selected insecticides were rotated annually at district level, and different insecticides were selected for adjacent districts in a mosaic pattern. The pyrethroids bifenthrin, cyfluthrin, deltamethrin and etofenprox were soon added as further insecticide options.
4. Susceptibility testing by the malaria control program continued on an annual basis, with the added insecticides tested, and with fixed sentinel sites across the island.
5. The results were entered into databases at provincial and national level, which also contained other entomological and epidemiological surveillance data. The data were

used in annual technical meetings by a task force with provincial representation to make coordinated decisions on the insecticides to be used in each district.

6. In case of emerging evidence of resistance to a particular insecticide, the rotational scheme was adjusted accordingly.
7. This evidence-based spray system was used over twenty years and has been accredited for its positive contribution to malaria control during that period[10].

V. PERIOD 4. ELIMINATION OF MALARIA (2009-2016)

1. When the civil conflict in districts where malaria incidence had remained high ended in 2009, Sri Lanka embarked for the third time on a malaria elimination program[11]. Surveillance activities were significantly stepped up.
2. The epidemiological surveillance system, which had included passive and active case detection, was further strengthened with targeted surveillance in receptive areas and among vulnerable populations to detect cases not reporting to health facilities. From 2006 onwards, each malaria case was investigated to differentiate locally-acquired cases from those imported. In 2008, surveillance capacity was enhanced for detection of the last sporadic cases, including in the private sector.
3. The entomological surveillance included a system of routine sampling at sentinel sites, supplemented with spot check in high-risk areas as well as 'reactive' entomological investigation at locations where malaria cases had been reported. Techniques were used to sample larval occurrence, adult mosquito behaviour, and insecticide susceptibility.
4. Monthly review meetings at central level provided a forum for sharing of data on surveillance between district officers and a technical task force, and to plan and target delivery of control interventions, including vector control.
5. IRS operations, stratified according to malaria risk, had previously made up the lion's share of vector control interventions. However, as malaria cases became scarcer, IRS was gradually replaced with long-lasting insecticidal nets, which were provided with international funding support[12].
6. Insecticide-treated bed nets and IRS were targeted to receptive areas and vulnerable populations, including gem miners, slash-and-burn farmers and security forces personnel.
7. Additional interventions were aimed at the vector's larval stage. This included larviciding, environmental modification, integrated pest and vector management, and use of larvivorous fish. Based on surveillance data, these interventions were targeted to gem mining areas, river beds bordering human habitation, irrigated rice systems, and locations of detected cases.
8. All these program efforts, together with the detection and prompt treatment of all sporadic cases, finally resulted in the interruption of malaria transmission[13]. The last

locally acquired cases were reported in October 2012. In 2016, Sri Lanka was certified malaria-free by the WHO.

VI. GOOD PRACTICES, AND LESSONS LEARNT

The Sri Lanka case presents several examples of good practices in relation to disease vector control.

Pesticide policy development

- *Independent evaluation*. As DDT resistance became widespread in 1976, an independent evaluation provided authoritative technical advice on malaria control[6]. This evaluation facilitated the introduction of drastic change, away from reliance on a long-used product, towards the development of new pesticide policy.
- *Policy based on essential evidence*. Two policy decisions were made: one to ban DDT, and one to restrict the use of malathion, as the DDT alternative, for malaria only. These decisions were informed by the results of sizeable pilot studies indicating the control failure of DDT, and demonstrating the effectiveness of malathion in reducing malaria cases. Interestingly, laboratory test results indicating the degree of insecticide resistance of the main malaria vector had been supportive but not decisive to the policy change.
- *Intersectoral agreement on pesticides*. To preserve insecticides for malaria control, and avoid resistance development due to agricultural use, an agreement was made between Ministers of Health and Agriculture to use malathion (and fenitrothion) in public health only, and ban all agricultural use. Legal status was given through the Malathion Control Act in 1985. This pesticide policy has cut across sectoral boundaries and addressed concerns of both public health and environment.

Insecticide resistance management

- *Reactive or proactive*. Insecticide resistance has been a constant threat to malaria vector control in Sri Lanka. The 'monotherapy' of IRS with DDT, and subsequently with malathion, inevitably resulted in vector resistance[7, 9].When resistance to DDT emerged, first, a reactive step taken was the replacement of DDT with malathion. Then, a proactive step taken in an attempt to delay the development of insecticide resistance was the restriction of malathion to malaria control.
- *Rotations and mosaics*. When more insecticides became available for malaria control, a rotational and mosaic system of IRS was introduced to actively prevent resistance. This system was informed by routine susceptibility testing at sentinel sites[10]. Entomological data were shared for coordinated decision making on insecticide selection and rotations, aiming to minimize the selection pressure on the vector.

- *Durable effectiveness*. The system of insecticide resistance management was functional over two decades (1994-2014). This was the period during which IRS operations, in combination with prompt diagnosis, treatment, and targeting of chemical and non-chemical vector control methods, successfully brought down malaria from 300,000 annual cases to nil.

Surveillance-based operations

- *From blanket operations to stratification*. Sri Lanka's epidemiological and entomological surveillance system evolved over the years. During the first eradication campaign (1958-1963), IRS operations were conducted as wide-scale blanket operations, and surveillance did not have an important role in informing on where and how to use IRS. Later on, epidemiological data were used to stratify districts according to malaria risk, and customize the spraying operations accordingly[6].
- *Using and sharing entomological data*. At sentinel sites, entomological surveillance on vector behavior (resting, biting, host preference), seasonal abundance, and insecticide susceptibility was routinely conducted. At district level, the data were used to verify suitability, and guide selection, of vector control products and methods, and timing and targeting of operations. Moreover, monthly coordination meetings at central level enabled the exchange of data and ideas between districts and with other experts to benefit decisions making. More recently, the growing database has been used to pinpoint high-risk transmission areas and select and target appropriate interventions.
- *Adding vector control methods*. After malaria 'hotspots' had been identified in slash-and-burn agricultural settlements, development projects, and gem mining areas, specific larval control and environmental measures were used at these sites to control the source of mosquito breeding.
- *Intensified surveillance*. In the final years towards elimination, as malaria cases became sporadic, surveillance activities were intensified to identify where transmission continued and to detect the last remaining infections. Control interventions, increasingly using insecticide-treated bed nets, became more precisely targeted to where needed.

Linkages with research

- *Demand-driven research*. A challenge for many programs is to have optimal support from research, and utilization of research outcomes. Over the years, the Sri Lankan program has benefited from various research studies on entomology and vector control, for example to identify secondary vectors in specific habitats not previously considered important[14-16]; the use of new control methods in specific transmission settings[17]; entomological studies in development areas cleared for irrigated agriculture[18, 19]; and vector control in irrigated rice systems [18, 19]. Nevertheless, a mechanism for interaction with programmatic activities had been lacking.

- *Task force mechanism*. More recently, routine meetings of a technical task force have improved the interaction of programme staff with researchers, which has benefited research prioritization, and strengthened decision making on vector control operations.

Other lessons

- *Safety screening*. Vector-borne disease control should closely coordinate with pesticide registration on the screening of vector control pesticides for their safety to human health and the environment.
- *Risks associated with development projects*. Irrigation and agricultural development projects, as well as gem mining activities, are a high risk for malaria outbreaks (and other vector-borne diseases). Such environmental projects must proactively conduct health impact assessments, to plan adequate preventive and control interventions that are based on ecological and socio-economic evidence.
- *Civil conflict*. Civil conflict undermines national efforts to eliminate malaria.

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