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Implementation of Indoor Residual Spraying of Insecticides for Malaria Control in the WHO African Region
Report

Vector Biology and Control Unit
Division of Healthy Environments and Sustainable Development
World Health Organization for Africa

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Contents

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Acronyms and abbreviations

Bti----------	Bacillus thuringiensis variety israelensis
CHAs----------	Community Health Agents
CHWs----------	Community Health Workers
DDT----------	Dichloro-diphenyl-trichloroethane
DEHO----------	District Environmental Health Officer
DFID----------	Department For International Development
DHMT----------	District health Management Team
DOMC----------	Division of Malaria Control
DVBD----------	Division of Vector Borne Diseases
EC----------	Emulsifiable Concentrate
EIR----------	Entomological Inoculation Rate
ESAMC----------	Eastern & Southern Africa Malaria Control
EHNRI ----------	Ethiopian Health and Nutrition Research Institute
FMOH----------	Federal Ministry of Health
GFTAM----------	Global Fund for HIV/Aids, Tuberculosis and Malaria
GMP----------	Global Malaria Program
IDP----------	Internally Displaced populations
IPO----------	International Professional Officer
IRS----------	Indoor Residual Spraying
IST/VBC/WA ----------	Inter country Support Team/Vector Biology and Control/West Africa
ITNs----------	Insecticide Treated Nets
IVM ----------	Integrated Vector Management
KEMRI ----------	Kenya Medical Research Institute
LLINs----------	Long Lasting Insecticidal Nets
LSDI ----------	Limpopo Spatial Development Initiative
MARA/ARMA----------	Mapping Malaria Risk in Africa/ Atlas du Risque de la Malaria en Afrique
MASEPA----------	Malaria Surveillance and Evaluation Partnership in Africa
MOH----------	Ministry of Health
NGO----------	Non Government Organization
NMCPs ----------	National Malaria Control Programs
NPO----------	National Professional Officer
PHO----------	Provincial health officer
PMI----------	President Bush malaria Initiative
PS----------	Private Sector
PT ----------	Partner
RTI ----------	Research Triangle Institute
SC ----------	Suspension Concentrate
SPC ----------	Space Spray Collection
USAID----------	United States Agency for International Development
VBC----------	Vector Biology and Control
WB----------	World Bank
WHO----------	World Health Organization
WHO/AFRO----------	World Health Organization Africa Regional Office
WP ----------	Wettable Powder

Executive summary

In the 1950s and 1960s the WHO led malaria eradication campaign eliminated the risk of malaria infection for about 700 million people mainly in Europe, Asia and Latin America within a period of about 20 years using IRS as a major tool. In the 1980s, following the global consensus to replace malaria eradication campaign by a long term control program, use of IRS was significantly reduced. In Africa, the intervention was abandoned except in some countries in southern and eastern Africa where IRS remained the corner stone of the malaria control strategy.

Since 2005 however, there has been a renewed interest in large-scale IRS programs. In the last 3 years the number of countries including IRS in their malaria control strategy and those expanding existing programs has increased. Consequently, the need for a systematic documentation of the progress of this intervention becomes pertinent. The aim of this report is therefore to present the current status of IRS operations, experience of each country and achievements in terms of level of operational and population coverage.

To date, 25 out of the 42 malaria endemic countries in the WHO African region have included IRS in their national strategy for malaria control. Of these, 17 countries routinely implement IRS as a major malaria control intervention; six are piloting IRS in a few districts, while 2 are planning pilot implementation with a view to scaling up further as they gain experience and skill. In the 2006-2007 malaria seasons a total of about 5 million units/structures were sprayed using different groups of insecticides. Average operational coverage[1] in target areas was 83% ranging from 16% in Kenya to 98% in Madagascar. A total of about 21 million people were covered.

Reduction in malaria transmission was documented in a number of countries including Botswana, Equatorial Guinea, Eritrea, Madagascar (in the IRS targeted areas), Mauritius, South Africa, Swaziland and Tanzania (Zanzibar), where the IRS programs are generally adequately resourced technically and financially. On the other hand, despite large-scale IRS applications in Ethiopia, Kenya, Mozambique, Namibia, Zambia and Zimbabwe status of impact of the intervention on malaria burden is unknown. In many of these countries inadequate technical and management capacity for effective IRS deployment and monitoring of its impact on malaria burden is a constraint. Shortage of, or inconsistent financing is a major challenge that partly contributes to most of the IRS program management shortcomings. In some cases, increased interest in scaling up IRS has not been matched by increased investment in capacity building required to run efficient programs. Notable exceptions to this are some of the newer IRS campaigns where the bulk (if not all) of the finances are from external partners.

IRS is expanding into highly endemic perennial transmission areas of the region. With this goes the need for intensive advocacy nationally and globally to ensure sustained political and financial commitment. This is essential in order to maintain the gains already achieved and to ensure that IRS programs are equipped with the required overall capacity to be able to deliver the intended impact on malaria as they expand. Inter-country, national and sub-national trainings should be conducted to provide planners and implementers with the required technical capacity. Focus on building sub-national technical capacity is of paramount importance due to the fact that in the majority of the countries IRS programs are decentralized whereby district health management teams are fully responsible for implementation. Countries should also capitalize on nationally available technical capacity to strengthen sub-national teams responsible for execution of IRS. Collaboration between NMCPs and local research institutes needs to be facilitated and supported to ensure evidence-based IRS management. Inter country collaboration through experience sharing and training should be promoted and supported. Emphasis should be given also on building logistics, managerial and system capacities at all levels.

[1] Number of structure actually sprayed in comparison to the number that was planned to be sprayed

1. INTRODUCTION

Effectiveness of indoor insecticide spraying in reducing malaria transmission and disease burden was first demonstrated in the 1930s in South Africa (Park Ross, 1936; De Meillon, 1936) and India (Covell et al., 1938). Indoor residual spraying (IRS) using DDT became a major component of the globally coordinated malaria eradication campaign in the 1950s and 1960s through which eradication and significant reduction of the disease was achieved in Europe, Asia, the Middle East, Latin America (Gramiccia & Hampel, 1972; Payne et al., 1976) and southern Africa (Zahar, 1985). For instance, in India, malaria incidence decreased from 75 million to about 100 000 cases per year during the eradication campaign (Sharma, 1987). In Sri Lanka child mortality was reduced by 50% between 1946 and 1956 (Newman, 1965 in Global Health Council, 2003). In Guyana malaria specific mortality was eliminated between 1945 and 1952 following introduction of IRS (Giglioli, 1972). In summary, the WHO led eradication campaign eliminated the risk of malaria for about 700 million people living in the sprayed areas within a period of about 20 years.

Based on these achievements of the eradication campaign, pilot projects were launched in tropical Africa, in Benin, Burkina Faso, Burundi, Cameroon, Kenya, Liberia, Madagascar, Rwanda, Senegal, Uganda and United Republic of Tanzania in the 1950s up to the 1970s (Garrett-Jones, 1964; De Zuleta et al., 1964; Kouznetsov, 1977; Bruce-Chwatt, 1984). These demonstrated that IRS can significantly reduce malaria transmission and burden even in highly endemic (intense transmission) areas (Payne et al, 1976; Zahar, 1985).

The remarkable results of the above small scale projects in the region were augmented by large scale pilots. In Pare-Taveta area of Kenya and Tanzania, the application of IRS using deildrin resulted in reduction of malaria transmission from an annual entomological inoculation rate (EIR) of 10-50 to less than 1 while crude mortality decreased from 24 per 1000 in 1955 to 16 in 1958 and infant mortality reduced from 165 to 132 per 1000 (Pringle, 1969). In the Garki district of Nigeria, introduction of IRS with propoxur significantly reduced malaria transmission and improved child and infant mortality (Molineaux & Gramiccia, 1980). Another pilot trial in Kisumu, Kenya resulted in the reduction of malaria transmission by 96% compared to baseline in two years of application of IRS (Payne et al, 1976). This level of reduction in transmission was associated with decrease of crude death and infant mortality rate by 43% and 41% respectively in the intervention areas. After IRS ceased, transmission and mortality rates increased in these areas.

Although the above pilot projects in different parts of the region demonstrated dramatic reduction of malaria transmission and incidence, IRS was not taken to scale in Africa except in epidemic-prone areas of southern and eastern parts of the region. This was due to the perception that transmission was intense and that without total coverage it would not be possible to have a great impact in terms of interrupting overall malaria transmission (Meek et al., 2001). As a result no considerable effort was made to tackle malaria in the African region and IRS was not taken to scale in most of the endemic countries as part of the global eradication campaign (Global Health Council, 2003; Mabaso et al., 2004).

In southern Africa where IRS continued to be a major pillar of malaria control, transmission was significantly decreased including in highly endemic areas such as the Okavango Delta of Botswana, Zambezi Valley in Zimbabwe, in Mozambique and Zambia (Zahar, 1985; Mabaso et al., 2004). In eastern Africa, unpublished reports of the malaria control program in Ethiopia indicated a significant reduction of malaria transmission following the launching of the malaria eradication program in the early 1960s that included IRS with DDT as the major intervention. In spite of all these achievements, until very recently application of the method has been generally declining. Following the global consensus to replace malaria eradication with a long term control program in the 1980s, use of IRS for malaria control was significantly reduced. In Africa, the intervention was completely abandoned in many countries except in some in southern and eastern Africa. This reduction of widespread use of IRS brought about significant resurgence of malaria incidence in a number of countries such as Ethiopia (Unpublished documents of the Malaria Control Program of Ethiopia; Sharma, 1996). Cessation of IRS with DDT in Sao Tome & Principe was followed by a serious upsurge of malaria transmission, while the most detrimental effect was documented in Madagascar where 10 000 deaths were recorded in a single epidemic in 1987-1988 (Mouchet et al., 1997). As recently as 2003, only about 12 countries in eastern and southern Africa were implementing IRS mainly to prevent and control epidemic malaria.

However, since 2005 a renewed interest has grown in implementing large scale IRS programs as a major component of the current malaria control efforts. Accordingly, WHO has taken important measures to strengthen and develop capacity for IRS by building consensus on some strategic issues, facilitating partnerships and ensuring effective collaboration to support national efforts to scale up IRS implementation. In 2006, WHO produced a position statement on the application of IRS for malaria control (World Health Organization, 2006). The statement highlights that IRS is one of the primary vector control interventions for reducing and interrupting malaria transmission and should be a major component of national malaria control strategies where the intervention is feasible and can be implemented effectively. The statement also indicates that WHO will support countries to collect and analyze data to determine potential effectiveness and feasibility of IRS in the national context, and also support countries in planning and implementation. It also requests national programs to report on coverage and impact as IRS is scaled up.

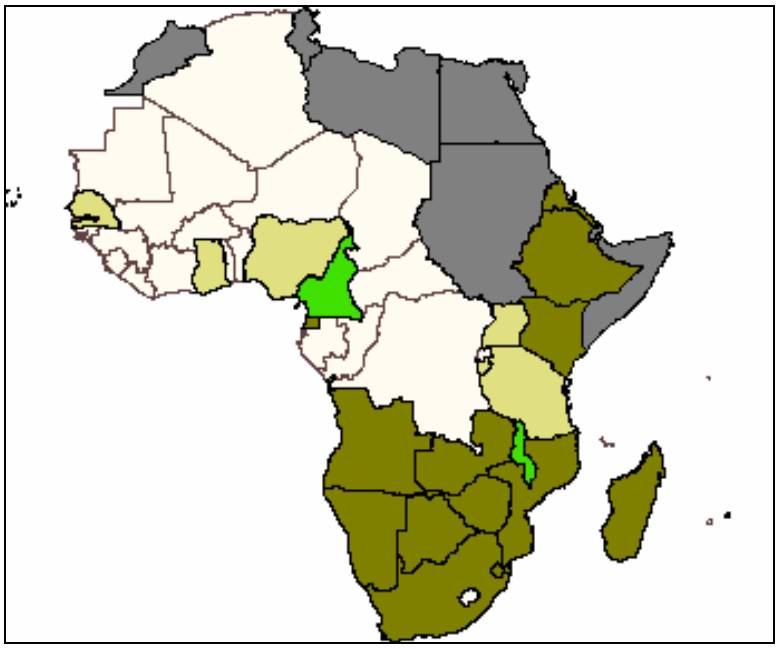
In June 2006, the WHO Regional Office for Africa organized a consultative meeting of vector control experts and country delegates to discuss the use of DDT for indoor residual spraying in the African Region. The meeting that was held on 20 – 22 June 2006 in Brazzaville, Congo endorsed the WHO's position and guidelines on effective and safe use of DDT for IRS (World Health Organization Regional Office for Africa, 2006). Summary of the final major endorsements and recommendations of the meeting is presented in Annex 1.

As a result of these statements many countries have opted to include IRS in their national malaria control strategies. In view of this continuing program expansion, monitoring progress in terms of population coverage and impact on malaria of IRS becomes imperative. The purpose of this report is therefore to document the current status of IRS operations at regional level and country experiences, population coverage and achievements in terms of transmission reduction. The report is divided into two major sections. The first section presents the regional overview of program implementation and coverage while the second one provides detailed analysis of status, experiences, coverage of IRS and impact on malaria in each country. The target audiences of this report are primarily national malaria control programs and their partners.

2. REGIONAL OVERVIEW

To date, 25 out of the 42 malaria endemic countries in the WHO African region have included IRS in their national strategy for malaria control (Fig.1). Of these, 17 countries routinely implement IRS as a major component of their malaria control strategy; six are piloting IRS in a few districts, while 2 are planning pilot implementation with a view to scale up as they gain experience and skill. In Botswana, Cape Verde, Eritrea, Ethiopia, Kenya, Madagascar, Mauritius, Namibia, South Africa, Swaziland and Zimbabwe, IRS is routinely applied to prevent and control malaria epidemics. In Equatorial Guinea, Mozambique, Sao Tome & Principe, Tanzania (Zanzibar Island) and Zambia, IRS is applied mainly in stable malaria transmission areas. With the exception of Equatorial Guinea, some places in Ethiopia, Lubombo Spatial Development Initiative (LSDI) in Mozambique and Zanzibar Island, IRS campaigns are conducted once a year.

Figure 1. Status of indoor residual spraying in the WHO Africa region, 2007



	Routine spraying: Angola, South Africa, Swaziland, Namibia, Botswana, Zimbabwe, Zambia, Mozambique, Madagascar, Mauritius, Kenya, Ethiopia, Eritrea, Sao Tomé & Principe, Equatorial Guinea, Cape Verde, Tanzania/Zanzibar
	Pilote spraying conducted: Burundi, Ghana, Nigeria, Senegal, Tanzania Mainland, Uganda
	Plan to pilot: Malawi and Cameroon
	Non AFRO
	No IRS

In 2006-2007 malaria seasons a total of about 5 million units/structures were sprayed using different groups of insecticides. Average coverage of unit structures (operational coverage) in target areas was 83% ranging from 16% in Kenya to 98% in Madagascar (Table 1).

Table 1: Summary of IRS country profiles, 2006-2007 malaria seasons

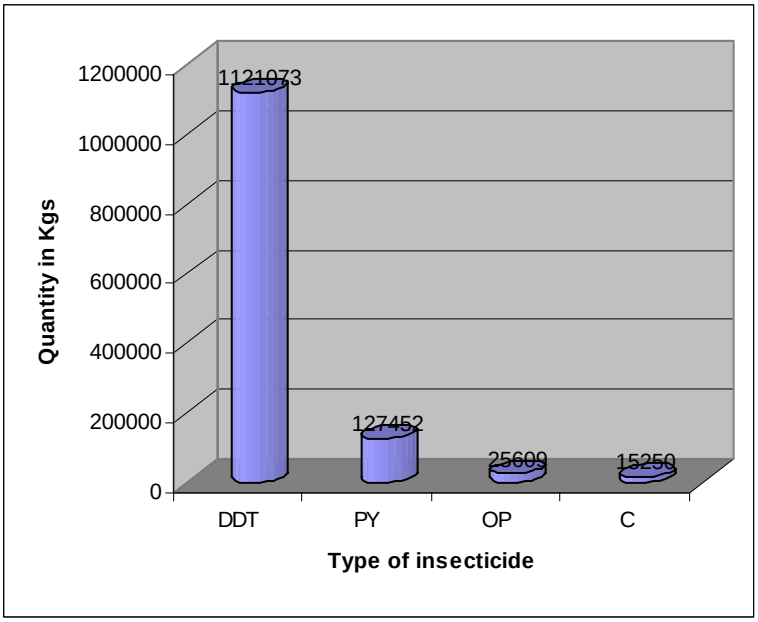
Country	Total pop. (million)	Pop. at risk (million)	Population covered (million)	Av. operational coverage (%)[2]	Insecticide used
Angola	15.4	15.4	0.65	95	LC
Botswana	1.7	0.7	0.43	73	LC
Burundi	7	6.6	0.098	96.5	AC
Eritrea	3.6	2.4	0.20	93	DDT
Ethiopia	73	50	5.98	87.2	DDT, ML
E. Guinea	0.5	0.5	--	60	BC
Ghana	21.5	21.5	0.23	--	PM
Kenya	32	22	0.55	16	D, L,
Madagascar	18	18	1.25	98	AC
Mauritius[3]	1.2	--	--	--	DDT
Mozambique	19	19	5.7	91	DDT, DM, LC, BC
Namibia	2	0.7	0.4	86	DDT, DM
Sao Tomé & Principe	0.15	0.15	0.14	87	AC
South Africa	45	4.5	4	83	DDT, DM, AC
Swaziland	1	0.5	0.4	93	DDT, DM
Tanzania/ Zanzibar	1.2	1.2	1.02	96	LC
Uganda	26	24.7	0.49	96	LC
Zambia	11	11	0.77	84	DDT, LC
Zimbabwe	12	5.5	2.2	82	DDT, LC

AC: alphacypermethrin; DM: deltamethrin; LC: lambdacyhalothrin, Ma: malathion; BC: bendiocard; PM: pirimiphosmethyl; DDT: Dichloro-diphenyl-trichloroethane; -- no information except for Mauritius
Source: Unpublished documents and reports of NMCPs

A total of about 1.3 million kgs of insecticide formulations was used for IRS in the above-mentioned countries (Fig 2 & Table 2). This included DDT, pyrethroids (lambdacyahlothrin, deltamethrin, alphacypermethrin), organophosphates (malathion, pirimiphosmethyl) and carbamates (bendiocarb). Five countries (Swaziland, Zambia, Zimbabwe, Namibia and South Africa) applied DDT and pyrethroids; seven countries (Angola, Botswana, Kenya, Madagascar, STP, Uganda & Zanzibar) used only pyrethroids; Eritrea sprayed only DDT while Ethiopia applied DDT and organophosphates (malathion). Only carbamate was used in Equatorial Guinea. Mozambique applied DDT, pyrethroids and carbamates. Ghana sprayed organophosphate (pirimiphosmethyl). In countries where DDT is used alongside other insecticides particularly pyrethroids, it is sprayed in rural type dwellings while pyrthroids are used to spray modern houses. The application of malathion in Ethiopia and that of bendiocarb in Equatorial Guinea and Mozambique is in response to lower susceptibility level of the malaria vector populations to either DDT or pyrethroids in some localities in these counties. Figure 3 shows countries applying the various insecticides.

[2] Average operational coverage is percentage of structures actually sprayed out of the number planned to be sprayed
[3] IRS with DDT is applied sporadically in response to case detection around the airport and other risk areas

Figure 2. Quantity of insecticide formulations used for IRS in the WHO African region, 2006 -2007



DDT- Dichloro-Diphenyl-Trichloroethane; PY-pyrethroid; OP-organiphosphate C-Carbamate
(Source: Unpublished documents and reports of NMCPs, 2006-2007)

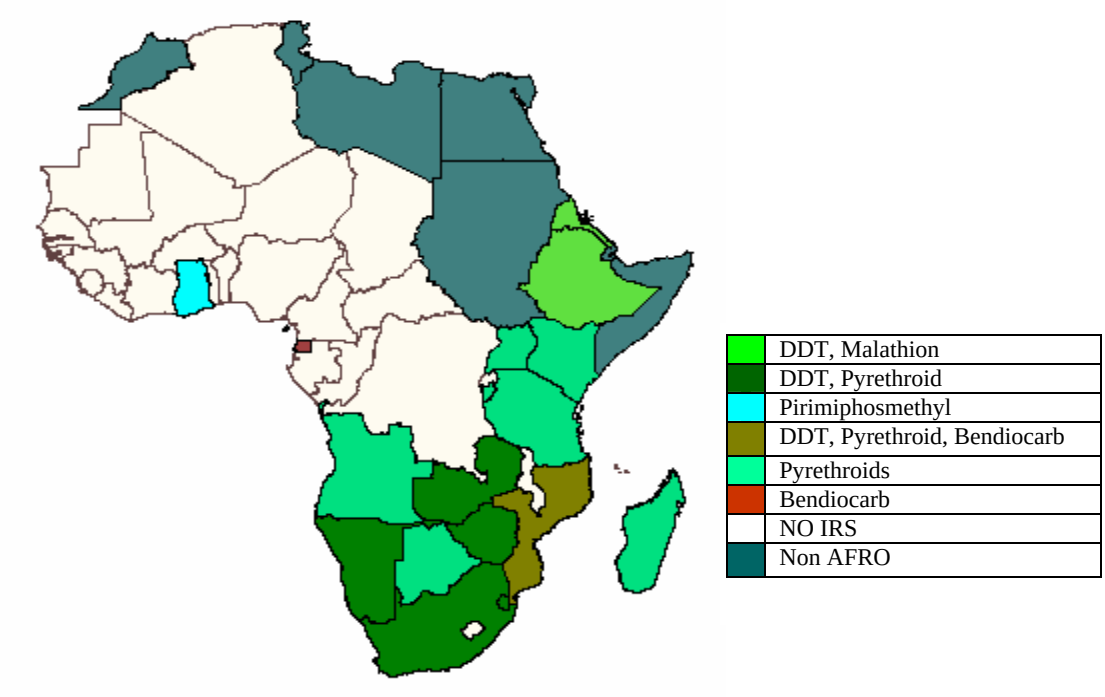
Table 2: Insecticides formulations (in kg) used for malaria vector control, 2006-2007

Country	DDT 75%	Lambda-cyhalothrin 10% WP	Alphacyper-methrin 5% WP	Delta-Methrin 5% WP	Malathion 10% WP	Pirimiphos methyl ---	Bendiocarb 80% WP
Angola	0	5 130	0	0	0	0	0
Botswana	0	1 734	0	0	0	0	0
Burundi	0	0	2 169	0	0	0	0
Eritrea	19 938	0	0	0	0	0	0
Ethiopia	495 212		0	0	7 049	0	0
E. Guinea	0	0	0	0	0	0	6000
Ghana	0	0	0	0	0	18 560	0
Kenya[4]	0	5604	0	1 280	0	0	0
Madagascar	0	0	17 000	0	0	0	0
Mauritius	500	00	0	0	0	0	0
Mozambique	410 250	51 000	0	408	0	0	9250
Namibia	52 815	0	0	2 741	0	0	0
Sao Tome	0	0	4 500	0	0	0	0
South Africa	87 433	0	890	4 766	0	0	0
Swaziland	10 050	0	0	257	0	0	0
Tanzania/ Zanzibar	0	592	0	0	0	0	0
Zambia	28 875	4 125	7 250	0	0	0	0
Zimbabwe	16 000	18 000	0	0	0	0	0
TOTAL	**1 121 073**	**86 185**	**31 815**	**9452**	**7049**	**18 560**	**15250**

-- Information on the quantity of applied insecticide formulation not available

[4] In addition, Kenya has used 3440 kg of PYMOS (natural pyrethrum)

Figure 3. Insecticides used for IRS in the various countries in the WHO African region, 2006-2007



About 25 million people were covered by IRS by the 2006-2007 malaria seasons. Reduction in malaria transmission and burden is reported from Botswana, Equatorial Guinea, Eritrea, Madagascar (in the IRS targeted areas), Mauritius, South Africa, Swaziland and Tanzania (Zanzibar) (Unpublished data and reports of National Malaria Control Programs, http://www.marathon.com/content/documents/fact_sheet/fact_sheets_malaria_September_2006; accessed on 15 October 2007). Some of these countries (Eritrea, Botswana, South Africa and Swaziland) are even foreseeing malaria elimination in the coming years using IRS as a major intervention. IRS programs in these countries are generally adequately resourced both technically and financially.

However, in many other IRS implementing countries overall capacity required for proper management of IRS programs needs further strengthening. Implementation, in many cases, is conducted with inadequate involvement of well trained staff and with limited up to date knowledge of the local vector(s) biology and dynamics. Capacity for regular supervision and quality monitoring, which are prerequisites for effective IRS, is inadequate. Assessment and documentation of impact on malaria is not conducted regularly due to inadequate involvement of staff with the required technical capacity, shortage of supplies and unavailability of robust documentation and reporting systems.

Adequate knowledge and capacity for proper and safe pesticide management is lacking (see country profiles). Shortage of appropriate storage and transportation facilities for insecticides and absence of maintenance workshops for spray equipment are notable problems affecting many IRS programs. Scarcity or inconsistent financing is a major challenge contributing to most of the IRS program management shortcomings. In some cases, increased interest in scaling up IRS has not been matched by increased investment in capacity building required to run efficient programs. Notable exceptions to this are some of the newer IRS campaigns where the bulk (if not all) of the finances are from external partners. But programs even in these countries should develop sustainability plans to consolidate the gains in malaria reduction beyond the life of the externally funded projects. It is also crucial to all IRS implementing countries to concurrently design strategies to expand the use of complementary interventions such as LLINs to consolidate and to keep up the gains that would be achieved through intensified implementation of IRS within the context of IVM.

Generally, IRS is expanding even into highly endemic perennial transmission areas of the region. With this goes the need for intensive advocacy nationally and globally to ensure sustained political and financial commitment. This is essential in order to maintain the gains already achieved, and ensure that IRS programs in countries such as Ethiopia, Kenya, Mozambique, Zambia and Zimbabwe are equipped with the required overall capacity to be able to deliver the intended impact on malaria as the IRS programs expand. Inter-country, national and sub-national trainings should be conducted to provide planners and implementers with the required technical capacity. Focus on building sub-national technical capacity is particularly of a paramount importance due to the fact that in the majority of the countries IRS programs are decentralized where by district health management teams are fully responsible for implementation. Countries should also capitalize on the nationally available technical capacity to strengthen sub-national teams responsible for execution of IRS. Collaboration between NMCPs and local research institutes needs to be harnessed and supported to ensure evidence-based IRS management. Inter country collaboration through experience sharing and training should be promoted. Emphasis should be given also on building logistics, managerial and system capacities at all levels.

2.1. Sub-regional overview

2.1.1. Southern Africa

In Southern Africa, IRS is the cornerstone of malaria control programs. About 15 million people in 9 countries [Botswana, Madagascar, Mozambique, Namibia, South Africa, Swaziland, Tanzania (Zanzibar Island), Zambia and Zimbabwe] are protected from malaria by IRS every year (unpublished documents and reports of NMCPs, 2006-2007). In Botswana, Namibia, South Africa and Swaziland almost all at risk populations are protected. In the remaining countries, priority for IRS is given to areas with very high malaria burden and high risk of epidemics. Mauritius has eliminated malaria using IRS with DDT. However, the program sporadically sprays isolated foci to control imported malaria cases (Unpublished report of the NMCP of Mauritius, 2006). In this sub-region, Malawi is planning for a pilot project in one district adjacent to areas where small scales IRS is routinely carried out by the private sector, particularly a Sugar Estate.

2.1.2. Eastern Africa

In eastern Africa (Ethiopia, Eritrea and Kenya) IRS is deployed selectively in priority epidemic prone areas. Tanzania (Zanzibar Island) applied IRS in almost all the households on the Island protecting more than one million people at risk of endemic malaria with financial support of the Presidents Malaria Initiative (PMI) in 2006. In the same year, about 8 million people were protected the sub-region (Unpublished reports of NMCPs, 2006). Burundi and Uganda conducted pilot IRS in one district each. The pilot in Uganda was supported by PMI. In Tanzania (Mainland) pilot spraying was carried out by the private sector in Dar es Salam city.

2.1.2 Central & West Africa

Angola, Sao Tome & Principe, Cape Verde and Equatorial Guinea routinely conducted IRS to control endemic and epidemic malaria. Angola sprays only in epidemic prone areas in the south west while Equatorial Guinea applies IRS in some of its highly endemic malaria areas. Spraying in Sao Tome & Principe and Cape Verde targets both epidemic and endemic malaria. The IRS programs in these countries cover about 2 million people. Ghana, Nigeria, Senegal have piloted IRS in selected areas with a prospect for expanding the program, while Cameroon is preparing to initiate spraying in a number of districts in 2008 with financial support from the GFATM.

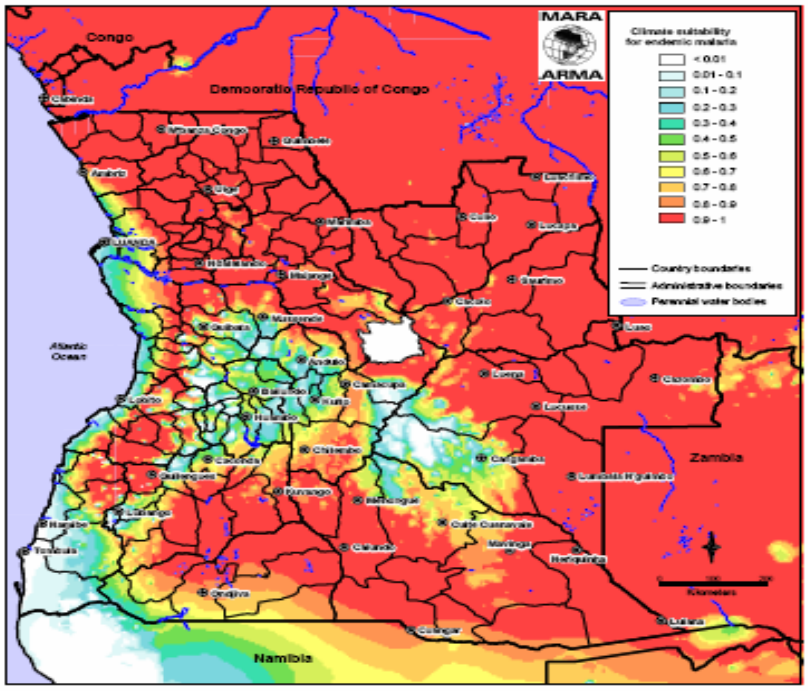
3. COUNTRY PROFILE

3.1. ANGOLA

3.1.1. Brief malaria epidemiology

Angola has a total population of 15 400 000 of which almost 100% is at risk of malaria (Fig 4), which is endemic in most parts of the country. A population of about a million lives in epidemic prone areas. A recently carried out survey on the importance and distribution of malaria vectors in some parts of Angola confirmed that *An. gambiae s.s* is the major and widespread vector. *Anopheles funestus* is also an important vector while *An. melas* plays a secondary role in coastal areas (Cuamba et al., 2006). The same authors reported that *An. arabiensis* was rare at least in the surveyed areas. *Anopheles gambiae* s.s is susceptible to pyrethroids and DDT.

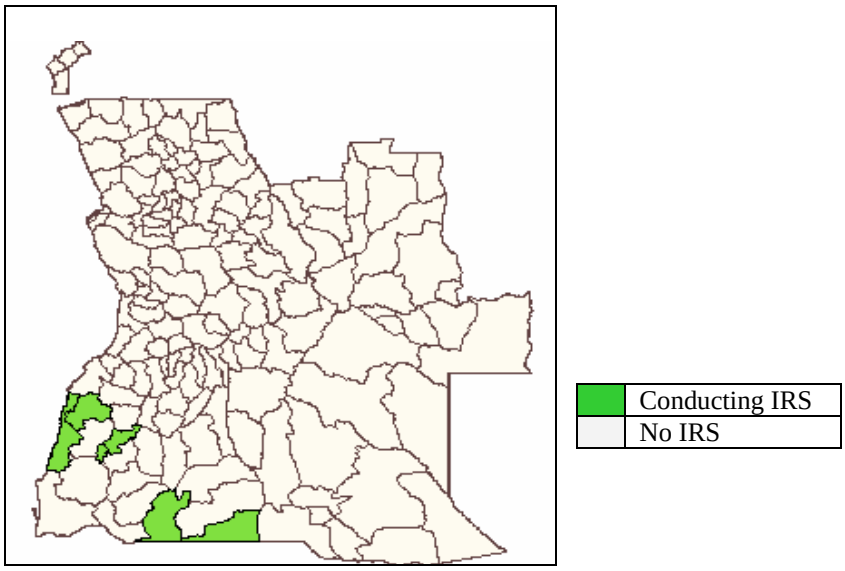
Figure 4. Malaria distribution and endemicity in Angola



3.1.2. Implementation and management of the IRS program

Until recently, ITNs were the mainstay of malaria prevention in Angola. In 2005 the national malaria control program in collaboration with its Namibian counterpart initiated IRS in the border area of Cunene Province within the context of "Cross Border Collaboration for Malaria Control". In 2006, the program was expanded with financial support from the GFATM and the PMI. In the same year, Research Triangle Institute (RTI) was contracted to spray areas supported by PMI while other areas were covered in the west of the country (Fig 5), reportedly protecting about 700 000 people.

Figure 5. Districts in Angola conducting IRS, 2006



Policy/strategy and population coverage in 2005-2006 malaria season[5]

Strategy/ implementation	No. structures targeted for spraying	Actual No. structures sprayed	Ave. operational coverage (%)	Pop. Protected	Trend of population coverage
- For Epidemic prevention and control - In urban/ peri-urban areas - Across the border with Namibia	Not reported	Not reported	Not reported	658 511	Increasing due to: - Increased resources from PMI - Increased collaboration with Namibia - Increased government commitment

Management and technical capacity

Basic documents	Planning	Spraying	Supervision	Funding
-No IRS strategic plan -IRS national guidelines not prepared	-National & district joint planning -Partners particularly PMI (RTI) involved	Conducted by: -CHWs & CHAs (311) -DHMT (22) -Partners (44)	- Supervisory check list available -Not done regularly in non-PMI implementation areas	-MOH -PMI -GFATM

Monitoring and evaluation

Quality assessment with contact bioassay	Test on vector susceptibility to insecticides	IRS impact evaluation	
		Entomological indicators	Malaria burden
-WHO standard test kits scarce -WHO standard protocol not available at the program level -Quality[6] of IRS is not monitored & reported regularly except in areas where RTI/PMI is spraying	-WHO standard protocol and test kits available - No baseline surveys carried out -No sentinel sites established -Trained staff available -Test carried out in 2005 in few sites	-Impact on vector population density and sporozoite positivity rate[7] not assessed	-Impact of IRS on malaria burden not evaluated

[5] Information on IRS implementation in 2007 has not been yet reported
[6] Refers to uniformly spraying of the optimum amount of effective insecticide on all sprayable surfaces

Maintenance and storage of spraying equipment

Storage capacity	Sprayers maintenance capacity
-Appropriate storage facilities available -Storage management checklist available -Staff responsible for storage available (RTI logistician)	-2 staff trained in basic sprayer maintenance techniques -Checklist for cleaning, proper handling and basic maintenance of sprayers available -Functional sprayer maintenance workshop available

Pesticide management

Regulatory legislatives	Transport & storage of insecticides	Handling, application & use of insecticides	Waste management
-Insecticides used for IRS are registered -Information on capacity for and practices of control of importation and quality control of insecticides not reported -Insecticides are taxed	-No checklist on safe transportation and storage -Appropriate storage facilities available	-No check list on proper handling of insecticides -Protective gear for safe handling of insecticides inadequate[8] -No specific education of spray operators on occupational safety and health -Monitoring/inspection of condition of sprayers regularly done in some districts -Public education for awareness & safety is not regularly conducted	-No checklist on proper disposal of pesticide containers, spray washes & other contaminated materials - Proper & safe disposal of the above not practiced at all times

Insecticides applied in 2005-2006 malaria season[9]

Type	Amount of formulation used (kg)	Active ingredient	Formulation
Lambdacyhalothrin	5 130	10%	Wettable powder (WP)

3.1.3. Perspectives

Indoor residual spraying for malaria control is a relatively new strategy in the malaria control program of Angola. The program has been strengthened and expanded during the last 2 – 3 years. To date, most people at risk of epidemics are protected. IRS is expected to further expand in the 2007 transmission season to include one more province along the border with Namibia. Capacity for IRS implementation and management is good particularly in areas supported by PMI. Supervision, monitoring and evaluation in non-PMI funded areas needs to be strengthened. Routine wall bioassays need to be conducted to evaluate the quality of the spray program.. There is a need to assess the impact of IRS on malaria transmission, morbidity and mortality. Data from baseline surveys need to be compared with post-intervention surveys. Development of a national IRS manual and strategic plan is imperative to ensure quality, standard and timely implementation of spraying. Harmonization of partners' involvement will be enhanced by the development of a national strategic plan adhered to by all partners.

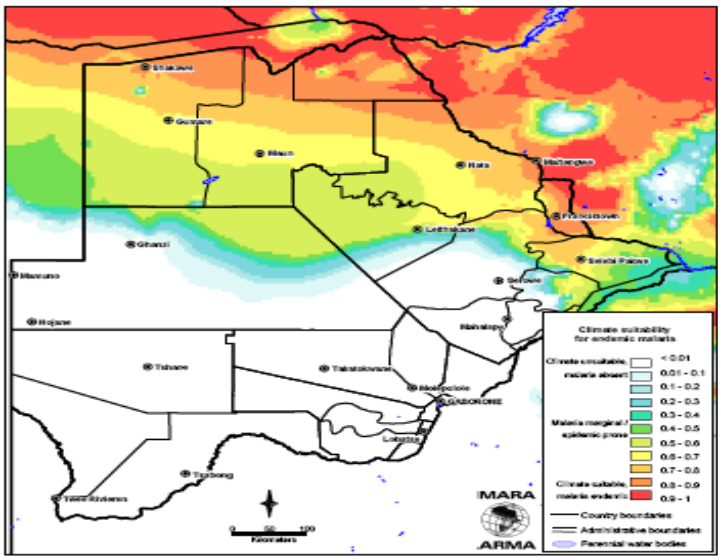
[7] Proportion (%) of female A*nopheles* mosquitoes with sporozoites in their salivary glands
[8] In terms of both completeness and quantity to protect all spray operators
[9] Information on insecticide use in 2007 has been reported

3.2. BOTSWANA

3.2.1. Brief malaria epidemiology

Botswana has a total population of 1 700 000 of which almost 700 000 (37%) is at risk of malaria. Malaria is distributed in the northern half of the country (Fig 6) and in most parts transmission is seasonal with only a few places of perennial transmission particularly in the Okavango and Chobe districts. *Anopheles arabiensis* is the single major vector. Vector characterization survey conducted in 2006 revealed that the species is distributed in all malaria areas of Botswana. *Anopheles arabiensis* is partially exophilic (outdoor resting), partially exophagic (outdoor biting) and partially zoophilic (biting animals as much as it does on humans). Recent tests revealed a reduced susceptibility level to pyrethroids particularly lambdacyhalothrin and deltamethrin, 89% and 92% respectively (Unpublished report of NMCP, Botswana) which calls for further investigation on the resistance mechanism, magnitude, distribution and its operational impact on the IRS program.

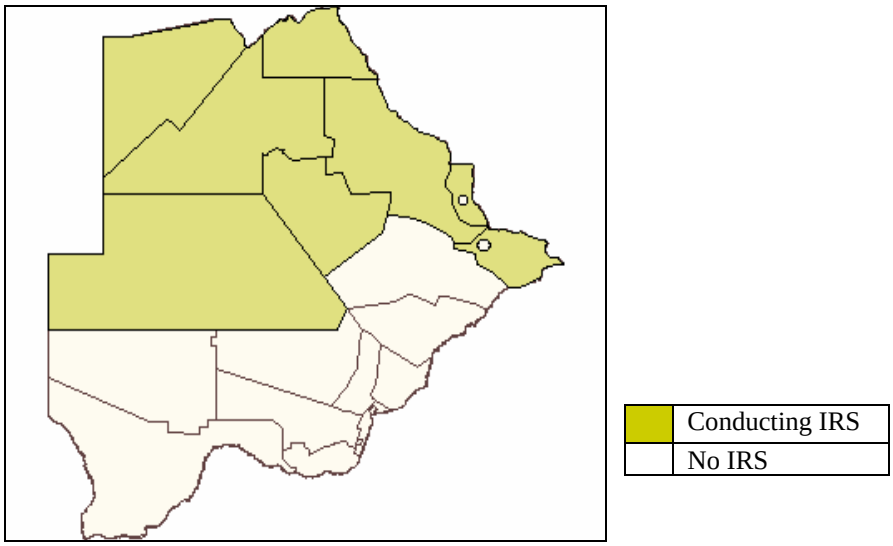
Figure 6. Malaria distribution and endemicity in Botswana



3.2.2. Implementation and management of the IRS program

Indoor residual spraying for malaria control in Botswana goes back to the mid 1940s when spraying of human dwellings was initiated. DDT spraying became an important vector control intervention in the 1950s (Mastbaum 1944 & Freedman 1953 in Mabaso et al., 2004). Small scale spraying of human habitations with DDT continued until 1974 when a national malaria control program was initiated. Already by 1973, spraying was implemented in malarious areas of three districts. In the 1980s a comprehensive vector control program was organized and continued the application of DDT in most malaria affected districts. DDT was the insecticide of choice until 1998 when it was replaced with lambdacyhalothrin (Unpublished documents of Ministry of Health of Botswana, 1999). Since then, only this insecticide has been used for IRS in all the districts (Fig 7).

Figure 7. Districts in Botswana conducting IRS, 2007



Policy/strategy and population coverage in 2006 -2007 malaria season

Strategy/ implementation	No. structures targeted for spraying	No. structures actually sprayed	Ave. operational coverage	Population Protected	Trend of population coverage
- Routine for epidemic prevention and control - In urban, peri-urban & rural areas - Planning to initiate cross border control with Zimbabwe	174 762 rooms	127 746 rooms	73% (Some districts report more than 80% while others do less than 65%)	500 000 (75% of the target population)	- Increasing following the re-launch of IRS with a view to eliminate malaria

Management and technical capacity

Basic documents	Planning	Spraying	Supervision	Funding
-Strategic plan available -National IRS guideline available	-Joint planning of national entomology unit & district environmental health departments -annual planning meetings and conferences take place	-DHMTs with the support of national entomology unit conduct spraying -273 trained personnel available	-No supervisory check list -But done regularly by entomologists	-Only MOH

Monitoring and evaluation

Quality assessment with contact bioassay	Tests on vector susceptibility to insecticides	IRS impact evaluation	
		Entomological indicators	Malaria burden
-WHO standard protocol and test kits available -8 trained staff available (2 entomologists, 6 technicians) -But contact bioassay not done regularly due to limited availability of sample mosquitoes	-WHO standard protocol and test kits available, though shortages experienced at times -No sentinel sites -8 trained staff (2 entomologists, 6 technicians)	-Vector indoor resting density monitored yearly by pyrethrum spray sheet collections (SPC) -Window trap catch occasionally conducted -Entomology unit does all the above	-Data on unconfirmed & confirmed malaria cases and deaths is documented but not analyzed in relation to IRS implementation

Maintenance and storage of spraying equipment

Storage capacity	Sprayers maintenance capacity
-Appropriate storage facilities available -No storage checklist -DHMT staff responsible for storage	-Number of staff trained in basic sprayer maintenance technique not known -No checklist for cleaning, proper handling and basic maintenance of sprayers -Functional sprayer maintenance workshop available at central level

Pesticide management

Regulatory legislative	Transport & storage	Handling, application & use	Waste management
-Insecticides used for IRS registered - Information on capacity for and practices of quality control of insecticides not reported -Insecticides for IRS taxed	-No checklist on safe transportation & storage of insecticides -Appropriate storage facilities available	-No check list on proper handling of insecticides by IRS personnel -Protective gear for safe handling of insecticides in most cases used -No specific education to spray operators on occupational safety & health -Monitoring/inspection of conditions of sprayers not regularly done -Public education for awareness and safety not regularly conducted	-No checklist on proper disposal of pesticide containers, spray washes & other contaminated materials - Proper & safe disposal of the above not practiced at all times

Insecticide application in 2006-2007 malaria season

Type	Amount of formulation used (kg)	Active ingredient	Formulation
-Lambdacyhalothrin	1734	10%	WP

3.2.3. Perspectives

In mid and late nineties, following the decentralization of its management to the district level, the IRS program experienced some problems of quality and standards. Through persistent government effort and WHO's support, the program in general has improved. Currently, capacity for IRS implementation and management is by and large good though operational coverage of lower than the optimal 80% is still reported from some districts. Most of the populations at risk of malaria is protected. Geographical and population coverage are expected to increase due to the re-launching of IRS in the context of malaria elimination. The number of districts reporting less than 1% malaria prevalence at least in some areas has been increasing during the last few years. However, no effort has been made to specifically establish the link between application of IRS and the reduction of the overall malaria burden. Botswana is planning to implement malaria elimination strategies in the next few years. Initiation of cross -border malaria control particularly with Zimbabwe is anticipated as part of limiting cross border malaria transmissions. Analysis of the data on unconfirmed & confirmed malaria cases and deaths in relation to IRS implementation is important to determine the impact of the intervention.

3.3. CAPE VERDE

3.3.1. Brief malaria epidemiology

Estimated population of Cape Verde is 231 000. Malaria transmission in Cape Verde is unstable with a short transmission period. The entire population is at risk of epidemics. *Anopheles arabiensis* with anthropophilic, exophagic and exophilic tendency is an important vector. It exists on most islands, while opinions are divided regarding its presence in some islands of the country. There is no information on the susceptibility level of *An. arabiensis* to insecticides of public health use in Cape Verde.

3.3.2. Implementation and management of the IRS program

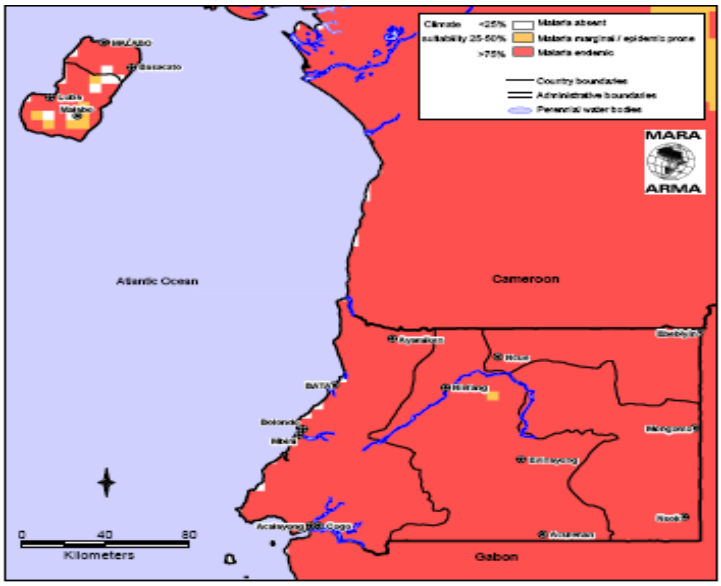
The application of IRS was started in 1948. According to unpublished NMCP documents, DDT was used to spray houses while the use of motor oil and larvivorous fish was intensified to control larvae in all areas of Cape Verde resulting in reported malaria eradication in the 1950s. Between 1950 and 1967 no malaria was reported from the country. *Anopheles gambiae* complex was eliminated from five islands: Sal, S. Vicente, Boa Vista, Maio, and Fogo. However, there was no agreement on the vector's complete elimination from the island of Santiago. Following the re-emergence of malaria in 1967 it is now believed that the vector had never been completely eliminated from the island of Santiago from which it spread and reestablished malaria transmission in the country. In the late 1970s malaria transmission gradually increased and in the 1980s Cape Verde experienced epidemics. The situation resulted in renewed application of malaria control interventions including IRS. In the last decade Cape Verde has been conducting IRS using pyrethroids and DDT. Malaria has been controlled and the risk of epidemics has been reduced. However, information on the size of the operation and population coverage, actual impact on malaria transmission, technical and managerial capacity and other relevant information are not available.

3.4. EQUATORIAL GUINEA

3.4.1. Brief malaria epidemiology

Equatorial Guinea has an estimated population of 500 000 of whom 100% are at risk of highly endemic malaria (Fig 8). *Anopheles gambiae* s.s. and *An. funestus* are the main malaria vectors (Berzosa et al. 2002, Cano et al. 2004). Both species exhibit a significant level of exophilic behavior during the dry season and distinct endophilly in the wet season (Cano et al 2004). *Anopheles melas* is known to play a subsidiary role in the southwest, south east and north part of the Bioko Island (Berzosa et al. 2002). But also *An. carnevalei* and particularly *An. moucheti* have been implicated as important malaria vectors in Equatorial Guinea (Cano et al., 2004). *Anopheles gambiae* s.s. is resistant to pyrethroids (Reimer et al., 2005; Bagayoko et al., 2005).

Figure 8. Malaria distribution and endemicity in Equatorial Guinea



3.4.2. Implementation and management of the IRS program

IRS for malaria control in Equatorial Guinea was initiated with the financial support of Marathon Oil Company and its business partners, and with technical assistance of the Medical Research Council in Durban, South Africa. The first spraying was launched in 2004 in Bioko Island. Number of structures sprayed with each spraying cycle until 2006 are presented in Table 3. Following the launch of spraying 80% reduction in sporozoite positivity rate in the vector populations and 33% reduction in malaria prevalence among children under the age of five years and pregnant women were documented on Bioko Island. In the 2nd year, 2005 the spraying of nearly 100 000 structures in four districts (Malabo, Luba, Riaba and Bany) resulted in 95% overall reduction of sporozoite positivity rate in the vectors and 44% reduction in malaria prevalence amongst the most vulnerable groups in comparison with the baseline data during the pre-spraying period.
(http://www.marathon.com/content/documents/fact_sheet/fact_sheets_malaria_September_2006; accessed on 15 October 2007). Reduction in malaria transmission and burden continued following implementation of subsequent rounds in the Island (Medical Care Development International, 2006). Abundance of *An funestus* has been reduced from average of 0.24 to 0 per trap night from 2004 to 2006, whereas that of *An. gambiae* reduced from about 0.5 to 0.02 during the same period. Accordingly, malaria prevalence among children has dropped from 45% to 26% during 2005-2006.

Table 3. Operational coverage of IRS in Bioko Island in Equatorial Guinea, 2004-2006

Round/year	No. structures planned (targeted) to be sprayed[10]	No. structures actually sprayed	Operational coverage (%)
R. 1/ 2004	130 000	93 353	72
R. 2/2005	130 000	92 440	71
R. 3/2005	130 000	103 099	79
R. 4/2006	130 000	109 171	84

(Quoted from Medical Care International, 2006)

In the 1st year, a pyrethroid insecticide (deltamethrin) was applied. In the second year reduced susceptibility of the vector to pyrethroids was detected. Consequently, about 6000 kg of bendiocarb (carbamate, unrelated insecticide to pyrethroids) was applied as part of insecticide resistance management tactic. Unlike to the previous rounds, the recently conducted spraying, Round 4, have achieved 84% operational coverage, which is above the minimum optimum (80%), required for effective IRS program (Table 3). detailed information on status of the IRS program, technical and managerial capacity of the national malaria control program and existing monitoring and evaluation, maintenance and other relevant issues in Equatorial Guinea.

3.4.3. Perspectives

The IRS program in Equatorial Guinea is well monitored and evaluated with the direct involvement of the partner institutions. Gradual development of national capacity to sustain the remarkable gains and to expand the intervention in other parts of the country is of paramount importance. In this regard, agreement has been made between the project and the Government of Equatorial Guinea to progressively transfer the program management responsibility to the national authorities. Reportedly, planning and implementation of the IRS project is conducted with the full involvement of the MOH and within the context of the existing systems (http://www.marathon.com/content/documents/fact_sheet/fact_sheets_malaria_September_2006; accessed on 15 October 2007). It is hoped that Equatorial Guinea will receive $26 000 000 from the GFATM to enable expansion of IRS onto the mainland.

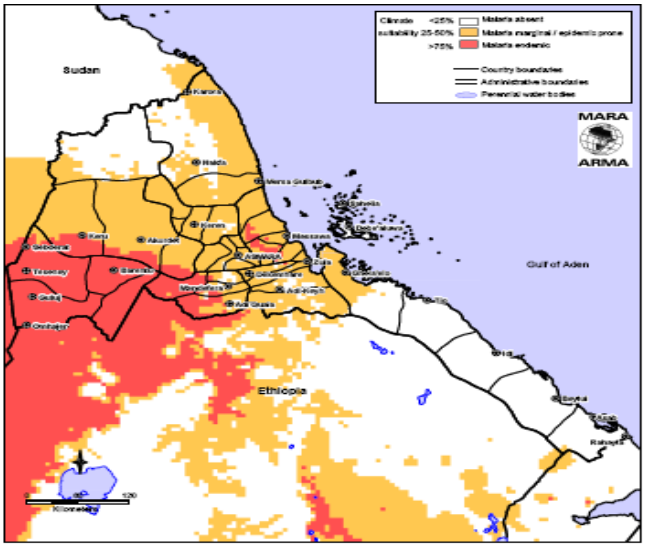
[10] Approximate numbers based on the estimate made in 2006

3.5. ERITREA

3.5.1. Brief malaria epidemiology

A total of 3 600 000 people reside in Eritrea. Of these about 2 400 000 are at risk of malaria of which 1 200 000 are particularly at risk of epidemics (Fig 9). Malaria in some parts of Eritrea is seasonal with risk of epidemics while in others it is perennial with seasonal peaks. *Anopheles arabiensis* is the major vector of malaria in all malarious areas of the country. The species is partially exophilic, exophagic and zoophilic. It is fully susceptible to most public health pesticides such as DDT and pyrethroids.

Figure 9. Malaria distribution and endemicity in Eritrea

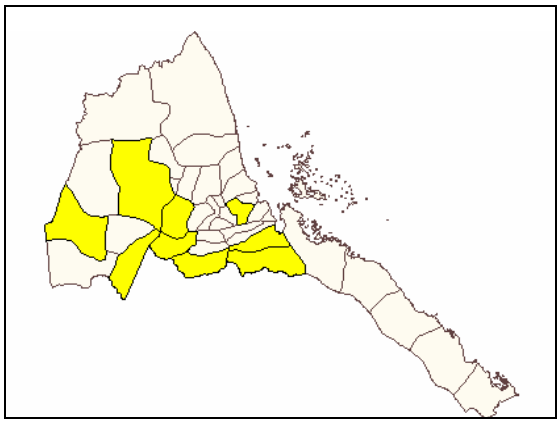


However, recent studies revealed a reduced susceptibility to malathion (organophosphate), which calls for further investigation and confirmation since it is sometimes used in place of DDT (Unpublished documents of Ministry of Health, Eritrea). Furthermore, malathion resistance has been documented in *An. arabiensis* in Sudan. Recently, *An. d'thali* and *An. cinereus* have been implicated with malaria transmission in Eritrea but are not expected to become major vectors.

3.5.2. Implementation and management of the IRS program

Indoor residual spraying in Eritrea started in 1965 as part of the global malaria eradication campaign. IRS with the application of DDT continued until late 1960s in almost all malarious areas of the country. Then the program was interrupted due to the prevailing political situation. A national malaria control program with IRS as a major component of the strategy was re-established in 1996. Since then, IRS has been implemented in most malarious areas, at the beginning with blanket coverage and later on using selective spraying approach. The use of only DDT for IRS continued until 2004 when malathion (organophosphate) was introduced in addition to DDT in some parts of the target areas due to reasons other than resistance. IRS in Eritrea currently covers areas in 9 districts in 3 zones (Fig. 10).

Figure 10. Districts in Eritrea conducting IRS, 2006



Policy/strategy and population coverage in 2006 malaria season

Strategy/ implementation	No. structures targeted for spraying	No. structures actually sprayed	Ave. operational coverage (%)	Population protected	Trend of population coverage
- Routine for epidemic prevention and control - In rural areas	74 275	69 778	93	208 377	-Decreasing due to increased selective spraying & reduction in malaria burden

Management and technical capacity

Basic documents	Planning	Spraying	Supervision	Funding
-Strategic plan available -National IRS guidelines available	- NMCP & DHMTs plan jointly -Planning meetings & annual conferences take place	-DHMTs with CHWs and CHAs -Actual spraying is done by trained temporarily hired personnel -No other partners involved	-Supervisory check list available -Done regularly by national and Zone office staff	-Government -WB -GFATM

Monitoring and evaluation

Quality assessment with contact bioassay	Test on vector susceptibility to insecticides	IRS impact evaluation	
		Entomological indicators	Malaria burden
-WHO standard protocol and test kits available -10 trained staff available -Done yearly after spraying but availability of kits is a problem	-WHO standard protocol and test kits available -26 sentinel sites established -10 trained staff available -Tests carried out annually.	-Impact on vector population density and sporozoite positivity rate not assessed	-IRS impact on malaria burden was evaluated in 2004 by NMCP and USAID

Maintenance and storage of spraying equipment

Storage capacity	Sprayers maintenance capacity
-No appropriate storage facilities. But construction of a warehouse planned with the support GFATM round 6 -Storage checklist available -Zonal malaria technicians responsible for storage	-20 permanent staff and 108 public health technicians trained in basic sprayer maintenance technique -Checklist for cleaning, proper handling and basic maintenance of sprayers available -There is a functional sprayer maintenance workshop

Pesticide management

Regulatory legislatives	Transport & storage	Handling, application & use	Waste management
-Insecticides for IRS registered -Importation of insecticides for IRS controlled -Quality of insecticides checked -Insecticides for IRS bought by government and taxed	-No checklist on safe transportation and storage of insecticides -Appropriate storage facility available but needs improvement	-No check list on proper handling of insecticides -Protective gear for safe handling of insecticides used all times -Spray operators inadequately educated on occupational safety & health -Monitoring/inspection of sprayers regularly done -Public education for safety awareness not regularly conducted	-No checklist on proper disposal of pesticide containers, spray washes & other contaminated materials -Proper & safe disposal of the above not practiced at all times

Insecticide application in 2006 malaria season

Type	Amount of formulation used (kg)	Active ingredient	Formulation
DDT	19 938	75% (2gm/m^2)	WP

3.5.3. Perspectives

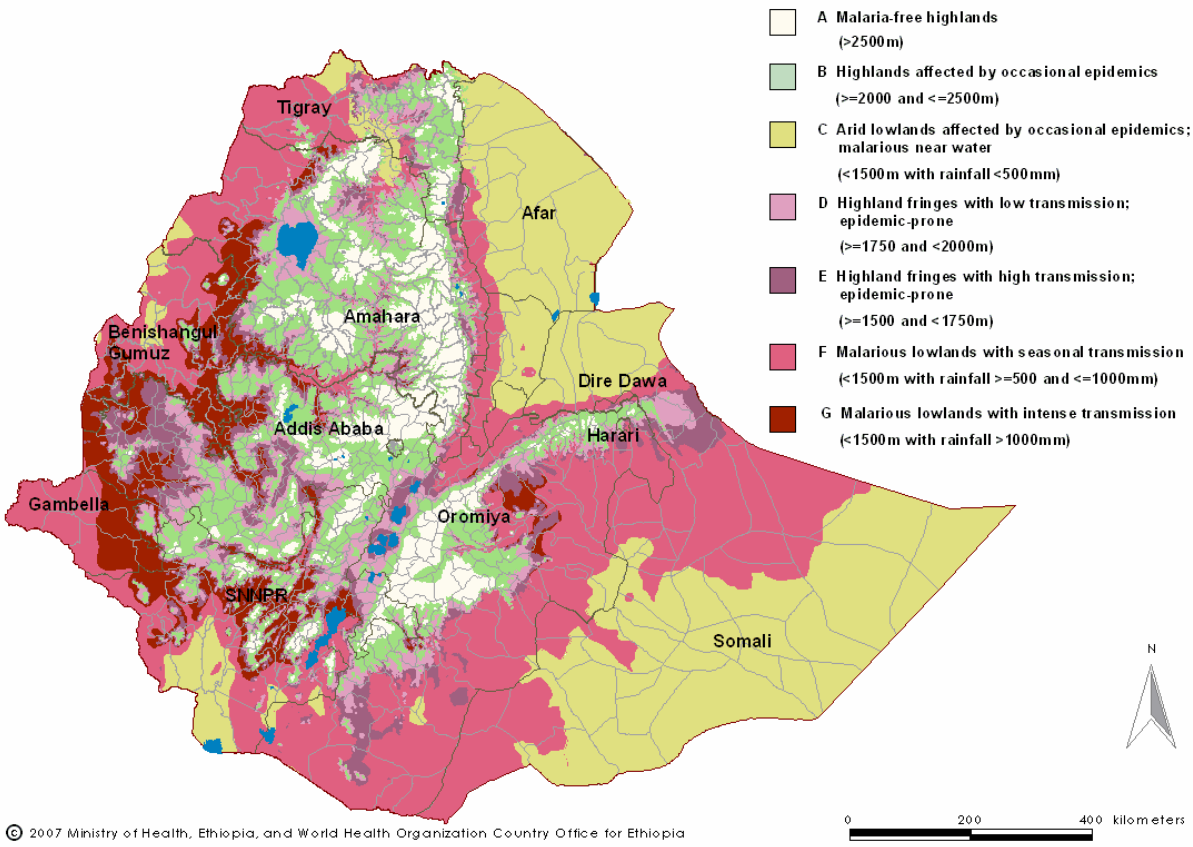
Indoor residual spraying remains one of the two main vector control strategies in Eritrea. The national malaria control program has been successful in the implementation of IRS and ITN in a complementary manner in different areas based on some epidemiological indicators. A sustained malaria burden reduction has been reported for the last few years in areas where both interventions are implemented. There is a tendency to reduce geographical coverage of IRS as malaria transmission in the country reduces and a selective spraying strategy is adopted. Nevertheless, more focused and targeted vector control programs including IRS will continue in order to further reduce malaria burden, consolidate gains and possibly eliminate malaria in the coming years.

3.6. ETHIOPIA

3.6.1. Brief malaria epidemiology

Ethiopia has a population of 73 000 000 of which about 50 000 000 are at risk of malaria. About 42 000 000 people are at risk of seasonal epidemics while the remaining about 8 million reside in perennial transmission areas Malaria in many parts of Ethiopia is seasonal with typical characteristics of highland transmission, i.e., very short transmission season with high risk of epidemics. Only in a few places, particularly in major river basins, is transmission perennial (Fig 11) with seasonal peaks. *Anopheles arabiensis* is the major vector. It is distributed in all malaria areas of the country. *Anopheles nili* plays a secondary role in some places. *Anopheles funestus*, which used to be an important vector has been eliminated from most, if not all, areas through many years of IRS application with DDT. *Anopheles arabiensis* in Ethiopia exhibits a partially (about 37%) exophilic behavior and it also is significantly zoohpilic (Ameneshewa & Service 1996). Its susceptibility to the main public health pesticides such as DDT and pyrethroids varies between areas. In a number of localities it is still susceptible while in others resistance is documented (Abate, A. et al., 2006, Unpublished data)

Figure 11. Malaria distribution and endemicity in Ethiopia



3.6.2. Implementation and management of the IRS program

IRS in Ethiopia was initiated in 1959 with the global malaria eradication campaign. Blanket spraying with DDT continued until the late 1970s in almost all affected areas. In the early 1980s, the eradication program was transformed into a control program with IRS as the major intervention. Blanket spraying was replaced by selective application. The use of only DDT continued until the early 1990s when time-limited replacement with malathion was considered in selected areas where vector populations resistant to DDT were encountered. At present, either DDT or malathion is sprayed in the different areas based on the local vector susceptibility to the two insecticides. During the 1990s, shortage of funding and supplies resulted in very scanty targeted spraying. Up to 2005, IRS was fully funded by government but is now partially supported by GFATM. In 2006 IRS was implemented in 2862

villages in all 10 administrative regions except in Addis Ababa. However, district-specific data on IRS operations is not readily available. Since the early 1990s, IRS operations were decentralized and are now entirely managed by regional and district health teams. Owing to low technical capacity for IRS at district offices and the lack of a robust IRS reporting system to the federal MOH, monitoring of the IRS program is very difficult. Hence, there is no reliable list at national level of districts that implement IRS.

Policy/strategy and population coverage in 2006 malaria season

Policy/ strategy	No. structures targeted for spraying	Actual No. structures sprayed	Ave. operational coverage	Pop. Protected	Trend of population coverage
- Routine for epidemic prevention and control - In periurban & rural areas	2 108 877	1 838 518	87.2%	5 984 485	Decreased during late 1990s to 2004 due to funding but is now on the increase.

Management and technical capacity

Basic documents	Planning	Spraying	Supervision	Funding
-Strategic plan available -National IRS guideline available	- Regional Health Bureaus & DHMTs plan jointly -Annual review & planning meetings take place	-Done by district health management teams -Actual spraying conducted by temporary hired spray operators -No other partner involved	-Supervisory check list available -Done regularly by regional and district offices	-MOH -GFATM

Monitoring and evaluation

Quality assessment with contact bioassay	Vector susceptibility to insecticides	IRS impact evaluation	
		Entomological indicators	Malaria burden
-WHO standard protocol and kits available -6 trained staff, mainly at national level, available -Not done regularly, conducted once in 1-2 years time[11], depending on capacity of the Regional Health Bureaus -Scarcity of entomologists within the NMCP at sub-national level is critical - Shortage of vector control trained technicians at implementation level is an impediment	-WHO standard protocol and test kits available -4 sentinel sites established -6 trained staff -Carried out in 1-2 years -Done in collaboration with EHNRI	-Impact on vector population density and sporozoite positivity rate not assessed due to lack of adequite technical capacity	-IRS impact on malaria burden not evaluated

Maintenance and storage of spraying equipments

Storage capacity	Sprayers maintenance capacity
-Appropriate storage available -Storage checklist available -District offices & Regional Health Bureaus responsible for storage	-Checklist for cleaning, proper handling and basic maintenance of sprayers available -No functional sprayer maintenance workshop -No trained staff in maintenance of sprayers

[11] Quality of spraying should be checked in representative localities during every spraying cycle

Pesticide management

Regulatory legislatives	Transport & storage	Handling, application & use	Waste management
-Insecticides used for IRS registered -DDT formulated locally, no information on its status of management -Quality of DDT and malathion checked -Insecticides for IRS taxed	-No checklist on safe transportation and storage of insecticides -Appropriate storage available in some districts	-No checklist on proper handling of insecticides -Protective gear for safe handling of insecticides not used all times -Spray operators inadequately educated on occupational safety & health -Monitoring/inspection of sprayers not regularly carried out -Public education for safety awareness not regularly conducted	-No checklist on proper disposal of pesticide containers, spray washes & other contaminated materials -Proper & safe disposal of the above not practiced

Insecticide application in 2006 malaria season

Type	Amount used (kg)	Active ingredient	Formulation
-DDT -Malathion	-495 212 -7049	-75% (2gm/m^2) -10% (2gm/m^2)	-WP -WP

3.6.3. Perspectives

The IRS program in Ethiopia has undergone several changes during the last 50 years of its existence. Geographical and operational coverage have fluctuated due to several reasons including policy shifts and resource constraints. Nevertheless, it remains the pillar of the malaria control program due to the unstable nature of malaria transmission which makes millions of people at risk of epidemics. It is however expected that, geographical and population coverage will increase in the coming years of scaling up vector control interventions within the context of IVM.

Decentralization of the IRS management to DHMTs without a clear routine reporting system to the federal MOH in place remains a critical impediment for the deployment of effective IRS. Quality and impact of IRS on malaria transmission has not been systematically evaluated. However, there are anecdotal reports that the frequency and magnitude of epidemics has declined in recent years since quality and standardized IRS implementation was revived. But, it also has to be noted that the use of long lasting insecticidal nets significantly increased during the same period.

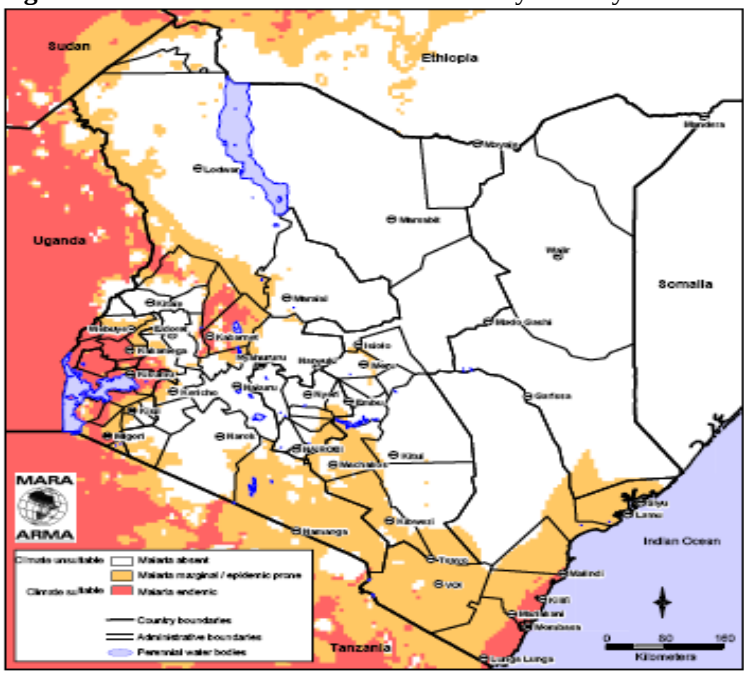
Lack of a national spray equipment maintenance center is a critical problem for such a large IRS program. Ideally, establishing one center in each region would assist districts to better maintain sprayers thus increasing their effective lifespan and the quality of spraying, which ultimately will reduce program costs. Ensuring safe storage of insecticides in all target districts is also important.

3.7. KENYA

3.7.1. Brief malaria epidemiology

About 32 000 000 people live in Kenya of which more than 22 000 000 are at risk of malaria. Out of these, about 9 200 000 people are at risk of epidemics while the remaining 12 800 000 live in perennial transmission areas. Districts situated in the south west, particularly adjacent to Lake Victoria, and the south east coastal areas experience perennial transmission whilst the western highlands and eastern fringes, where about 8 million people live, experience yearly epidemics (Fig 12) that are related to the rainy season. In the remaining northeastern arid areas occasional epidemics occur following unusual rainfalls and floods. The capital Nairobi and 9 other districts are at low risk or are free of malaria transmission. *Anopheles gambiae* s.s, *An. arabiensis* and *An. funestus* are the main vectors in Kenya.

Figure 12. Malaria distribution and endemicity in Kenya



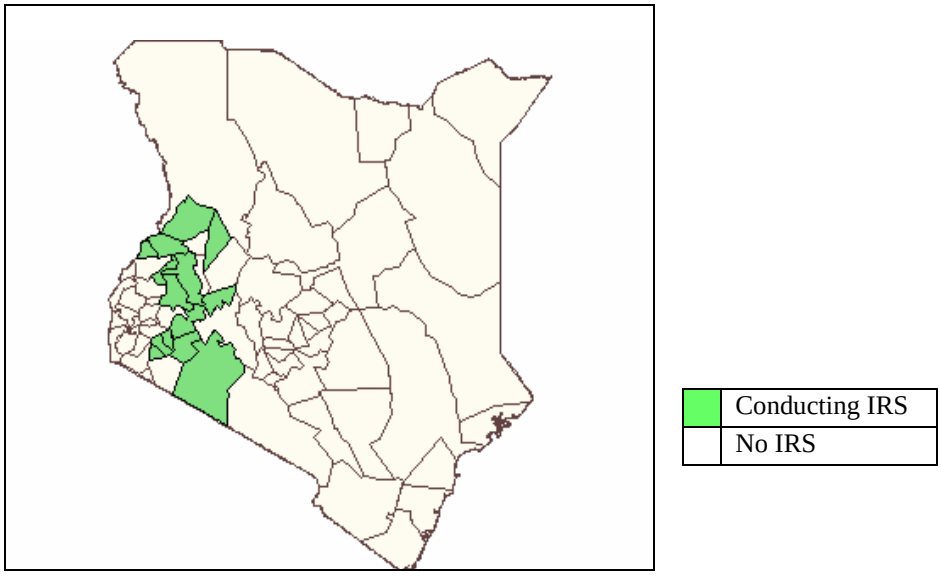
3.7.2. Implementation and management of the IRS program

Kenya was one of the countries where pilot IRS projects were initiated in the 1950s and 1960s as part of the global malaria eradication campaign. The Pare Taveta IRS project in Kenya and Tanzania was implemented between 1955 and 1959 using dieldrin. The project resulted in a complete disappearance of *An. funestus*, a strongly anthropophilic and endophilic species while the *An. gambiae* complex was reduced by 80%. The impact on the *An. gambiae* complex was less dramatic than that on *An. funestus* which may have been the result of the presence of *An. arabiensis* which is less endophilic and anthropophilic in its behavior than *An. funestus*. The sporozoite rate was reduced to < 1% and the *Plasmodium* index amongst children was reduced from 35% to below 5% (Kouznetsove, 1977; Bradley, 1991; Najera, 2001). However, when the spraying ceased, both vector abundance and malaria transmission rate increased.

Later on, another pilot project was conducted in 1973 – 1975 in the Kisumu area bordering Lake Victoria using fenitrothion (40% WP). There was a 96% reduction in infection incidence, 43.5% reduction in overall mortality, 65.6% reduction in disease prevalence, 40.8% reduction in infant mortality and 96% reduction in infection inoculation rate were achieved (Payne et al, 1976). Cessation of the spraying was followed by a rebound of the malaria transmission and burden to the pre-project levels.

After the eradication campaigns, routine IRS has not been implemented in Kenya for malaria control other than small scale sporadic spraying in response to epidemics. The Division of Malaria Control (DOMC) created in the late 1990s considered ITNs the major vector control strategy. The National Malaria Strategy (NMS 2001 - 2010) recommends selective IRS only for epidemic control. However,, due to repeated epidemics in the Kenyan highlands, in 2003, DOMC decided to implement large-scale IRS to prevent and control epidemics. But still small-scale implementation of IRS continued until 2004 due to limited financial and technical resources. Since 2005 progressive capacity building at district level has resulted in training of 30 District Trainers and 1700 spray operators. In 2006, areas at high risk of epidemics in 16 districts were sprayed and protected from potential epidemics (Fig 13). Spraying was also conducted in some arid areas in response to sporadic epidemics following above normal rains and floods.

Figure 13. Districts in Kenya conducting IRS, 2006



Policy/ strategy and population coverage in 2006 malaria season

Policy/ strategy	No. structures targeted for spraying	No. structure actually sprayed	Ave. operational coverage	Population protected in 2006	Trend of population coverage
- Routine IRS for epidemic prevention and control - IRS in epidemic response - In rural areas	680,000	110 365	16%	About 550 000 people	Increases as: -More resources are made available -Capacity increases -IRS accepted by policy makers

IRS management and technical capacity

Basic documents	Planning	Spraying	Supervision	Funding
-Strategic plan being developed with the context of IVM -No national IRS guidelines but spray operators manual available	-Joint planning of DOMC, DEHO & DVBD at national level -DHMT at district level -Merlin is also involved	-DHMT with CHWs and CHAs	-Supervisory check list not available -Not done regularly by provincial and national staff	-Government -GFATM -WHO/DFID -ADB

Monitoring and evaluation

Quality assessment with contact bioassay	Vector susceptibility to insecticides	IRS impact evaluation	
		Entomological indicators	Malaria burden
-WHO standard protocol and test kits not available at program level -Not done due to scarcity of supplies and technical capacity at the sub-national level[12]	-WHO standard protocol & test kits available -No established sentinel sites -No trained staff at sub-national level -No test done -Some information from Kisumu available at KEMRI, but not availed to the NMCP	-Impact on vector population density and sporozoite positivity rate not assessed due to limited entomological capacity at sub-national level	-IRS impact on malaria burden not evaluated, data flow between peripheral health system & DOMC not functional & little effort is made to link malaria data to IRS implementation

Maintenance and storage of spraying equipment

Storage capacity	Sprayers maintenance capacity
-No appropriate storage facilities -No storage checklist -Divisional PHO at implementation level & DOMC at central level are responsible for storage of sprayers	-Checklist for cleaning, proper handling and basic maintenance of sprayers not available but the spray operators' manual contains some instructions, no checklist to ensure compliance -No functional sprayer maintenance workshop in all districts or at national level -No trained staff in maintenance of sprayers

Pesticide management

Regulatory legislatives	Transport & storage	Handling, application & use	Waste management
-Insecticides for IRS registered -Importation of insecticides controlled - Information on capacity for and practices of quality control not reported -Insecticides for IRS taxed	-Checklist on safe transportation & storage of insecticides available -Shortage of appropriate storage	- Checklist on proper handling of insecticides available -Protective gears for safe handling of insecticides not used all times -Spray operators inadequately educated on occupational safety & health -Monitoring/inspection of sprayers not regularly done -Public education for safety awareness not regularly conducted	-No checklist on proper disposal of pesticide containers, spray washes & other contaminated materials -Proper & safe disposal of the above not practiced

[12] Entomological capacity at national level is strong in Kenya. However, harnessing this to the sub-national level remains a challenge

Insecticide application in 2006 malaria season

Type	Amount of formulation used (kg)	Active ingredient	Formulation
-Lambdacyhalothrin - Deltamethrin -PYMOS (natural pyrethrum)	-5 604 -1 280 -3 440	-10% -5% -pyrethrin	-WP -WP -EC

3.7.3. Perspectives

Large scale implementation of IRS is relatively new in Kenya. It has evolved from being an epidemic response tool to a routine epidemic prevention and control strategy with increased geographical, operational and population coverage. For instance in 2005, 91 186 structures were sprayed. The number increased to 110 365 in 2006. There is strong government and partner commitment to scale up quality IRS in Kenya. Annual spraying of epidemic prone areas is now the preferred strategic approach. Ministry of Health has elaborated a plan to expand coverage progressively to protect 4 million house units in subsequent rounds of spraying using financial support from Global Fund, PMI, ADB and DFID.

Generally, overall program management and system capacity at implementation (district) level needs further strengthening. Emphasis should be given to improve the very low operational coverage (16%) in the already targeted areas even before increasing the geographical coverage of the spraying. The technical capacity in malaria entomology and vector control available at national level should be used effectively to build capacity within the district health teams, who are responsible for program implementation. Supervision and monitoring quality of IRS needs special attention. As in many other countries in the region impact of IRS on the vector population density and malaria transmission in terms of sporoziote positivity rate is not assessed, nor has malaria burden been evaluated in relation to IRS implementation to guide program planning and implementation. It is envisaged that these technical and operational aspects of IRS will be ironed out once the above mentioned draft IVM Policy is operationalised. Urgent attention should be given to strengthening the ties between the operational malaria control programs and the research institutions to provide support in resistance monitoring and evaluation.

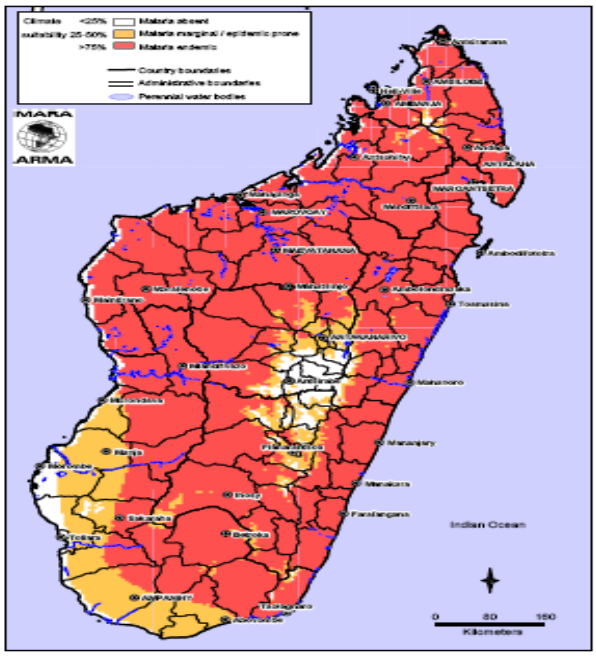
3.8. MADAGASCAR

3. 8.1. Brief malaria epidemiology

About 18 000 000 live in Madagascar. The whole population is at risk of malaria (Fig 14) and about half is at risk of epidemics. Malaria in parts of Madagascar particularly in the western and Eastern lowlands is stable with perennial transmission while the central highlands experience unstable transmission and are prone to epidemics. Here *An. funestus* is the major vector while *An. arabiensis* plays a secondary role. In southern semi desert areas of the country malaria is very unstable due to sporadic rains. Here too *An. funestus* and *An. arabiensis* are major and secondary vectors respectively while *An. gambiae* s.s. contributes to a very localized transmission. Also, *An. mascarensis* has been implicated in malaria transmission in some parts of Madagascar. The northern and eastern coastal areas have stable malaria and transmission is intense. *Anopheles gambiae* s.s. is the most important vector in these areas whereas, both *An. funestus* and *An. arabiensis* play a secondary role. Another distinct type of transmission is found in the western coastal areas where intensity of malaria transmission is moderate and *An. funestus* is a very important vector here as well.

Recently carried out tests revealed that *An. funestus* exhibit reduced susceptibility to DDT while *An. arabiensis* showed some level of resistance to the same insecticide and pyrethroids (Guillet & Govere, 2005). Information on the susceptibility status of *An. gambiae* s.s. to these insecticides is lacking.

Figure 14. Malaria distribution and endemicity in Madagascar

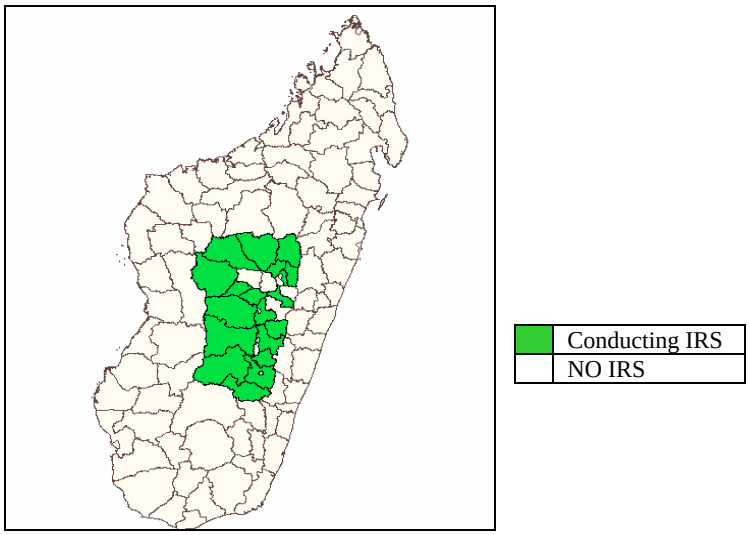


3.8.2. Implementation and management of the IRS program

Application of IRS for malaria control in Madagascar was started in 1950.. Malaria transmission was interrupted in the Central Highlands where malaria is unstable and significantly reduced in perennial transmission areas. The program continued until 1970 when it was stopped due to the failure in the anticipated eradication of the disease in the perennial transmission areas. In 1988, however a devastating epidemics occurred in the central highlands resulting in about 10 000 deaths. This severe resurgence of transmission led to the reintroduction of IRS in the Central highlands in the 1989/1990 malaria season. During the malaria seasons of 1998 -1999, 2000 - 2001 and 2001 - 2002 spraying was not consistently done due to limited funding. In 1999- 2000 spraying was conducted using DDT. Since 2003 IRS is applied selectively targeting areas at most risk of epidemics. IRS remains the major

intervention in the central epidemic prone highlands (Fig 15) while ITNs are intensively promoted in intense and moderate transmission areas of the country.

Figure 15. Districts in Madagascar conducting IRS, 2007



Policy/ strategy and population coverage in 2006-2007 malaria season

Policy/ strategy	No. structures targeted for spraying	No. structures actually sprayed	Average operational coverage	Population protected	Trend of population coverage
- National malaria strategic plan includes IRS - Routine IRS for epidemic prevention and control in peri-urban & rural areas	209 890	205 395	98%	1 250 000	Will increase for 2-3 years[13], then reduces as selective spraying of only localities at a high risk of epidemics continues based on epidemiological surveys

Management and technical capacity

Basic documents	Planning	Spraying	Supervision	Funding
-There is strategic plan -Policy document available -National IRS guidelines available	- National, provincial and district malaria staff plan jointly	-Done by DHMTs with trained spray operators from the local communities	-Supervisory check list available -Done regularly by national, provincial and district staff	-MOH -Project CRESAN II (WB) in 2006

[13] Blanket spraying for about 3 years to further reduce malaria burden in the highlands. Then, selective spraying will be adopted

Monitoring and evaluation

Quality assessment with contact bioassay	Test on vector susceptibility to insecticides	IRS impact evaluation	
		Entomological indicators	Malaria burden
-WHO standard protocol and test kits available -There is trained staff in the program -Done in 2006, but not regularly	- WHO standard protocol and test kits available -Sentinel sites established -Trained staff available in the program -Done once every 2 years	- IRS impact on vector population monitored through indoor resting & human landing catches & sporozoite positivity rate - Done in 2006 by the NMCP staff	-IRS impact on malaria burden evaluated

Maintenance and storage of spraying equipment

Storage capacity	Sprayers maintenance capacity
-Appropriate storage facility available -Storage checklist available -MOH central and district stores are responsible for storage of sprayers	-Checklist for cleaning, proper handling and basic maintenance of sprayers available -There is functional sprayer maintenance workshop -3 private agents are hired for maintenance of sprayers

Pesticide management system and capacity of the IRS program

Regulatory legislatives	Transport & storage	Handling, application & use	Waste management
-Insecticides for IRS registered -Importation of insecticides controlled -Quality of insecticides checked -Insecticides for IRS not taxed	-No checklist on safe transportation & storage of insecticides -Appropriate storage available	-No checklist on proper handling of insecticides -Protective gears for safe handling of insecticides not used all times -Spray operators not adequately educated on occupational safety & health -Monitoring/inspection of sprayers not regularly done -Public education for safety awareness not regularly conducted	-No checklist on proper disposal of pesticide containers, spray washes & other contaminated materials - Proper & safe disposal of the above not practiced at all times

Insecticide application in 2006-2007 malaria season

Type	Amount of formulation used (kg)	Active ingredient	Formulation
Alphacypermethrin	17 000 kg	5%	WP

3.8.3. Perspectives

IRS has been an important component of the malaria control strategy in Madagascar for several years. The method plays a critical role in the central highlands where severe epidemics can occur. Reportedly, here it has achieved a significant reduction in malaria burden. Now, there is a plan to conduct blanket spraying in the highlands for three consecutive years to eliminate *An. funestus*, the most important vector and most amenable to IRS due to its strong endophilic behavior, and then create a buffer zone of about 10 km between the highlands and the coastal area. This will be achieved by flooding the buffer zone with LLINs to stop the re-infestation of the highlands by *An. funestus*. During the three years of intensive IRS in the highlands, the surveillance system will be strengthened to enable the program to pinpoint residual transmission foci. The introduction of pyrethroids in 2006 to replace DDT is partly to delay possible resistance to this insecticide. However, the presence of pyrethriod-resistant *An. Arabiensis* as a secondary vector in the highlands needs a particular attention. Mass use of LLINs might further select pyrethriod-resistant populations. Instead, one may consider spraying with "Cordon Sanitaire" approach with a sequence of different insecticides. Generally, the NMCP has a good IRS management system and capacity.

3.9. MAURITIUS

3.9.1. Brief malaria epidemiology

Total population of Mauritius is 1.1 million. Prior to the launch of the malaria eradication program, mainly with IRS, intensity of malaria transmission was intermediate and unstable. *Anopheles funestus* and members of the *An. gambiae* complex were the main vectors. Following an intensive implementation of IRS in 1949-1951 throughout the country *An. funestus* disappeared completely and the *An. gambiae* complex density decreased significantly. This resulted in reduction of child parasite positivity rate from 95% to 0.62%, outpatient attendance from 46 000 to 23, mortality in hospitals from 1580 to 61 and crude death rate from 23.8% to 14.8% (Dowling 1951 in Kouznetsov, 1976). By 1973 malaria was officially eradicated from Mauritius. But the vector mosquito, now identified as *An. arabiensis* still existed. Earlier *An. merus* had been identified and in 1980 *An. gambiae s.s.* was also recorded on Mauritius (Zahar, 1985). Transmission was re-established in 1975 when the country was hit by severe cyclones (WHO country cooperation strategy, Rep of Mauritius, 2004-2007). The epidemic was contained through the application of IRS and case management. Since then, limited reports of indigenous malaria cases continued until 1997 when only one case was reported. However, Mauritius continues to experience a problem of imported malaria. The vector, *An. arabiensis* is susceptible to insecticides in use by the program, DDT and temephos (larvicide).

3.9.2. Implementation and management of the IRS program

The risk of local malaria transmission in Mauritius is real due to the large number of infected travelers and presence of vector mosquitoes. As a result, malaria control interventions continued particularly in areas with high risk of imported cases and transmission. Also, the Ministry of Health is carrying out rigorous entomological surveillance in selected villages and around the harbor and airport, where there have been reports of infective malaria vectors. Larval habitats are treated with temephos, and DDT is sprayed in the residences in areas where there have been indigenous cases of malaria and on routine basis (six monthly) along the harbor and airport areas. In 2006, 500 kg of DDT was applied for this purpose. In general, the anopheline density in Mauritius is low, but following the big summer rains, especially during a period of cyclones, there is a considerable increase of larval habitats and consequently a propagation of the vector.

3.9.3. Perspectives

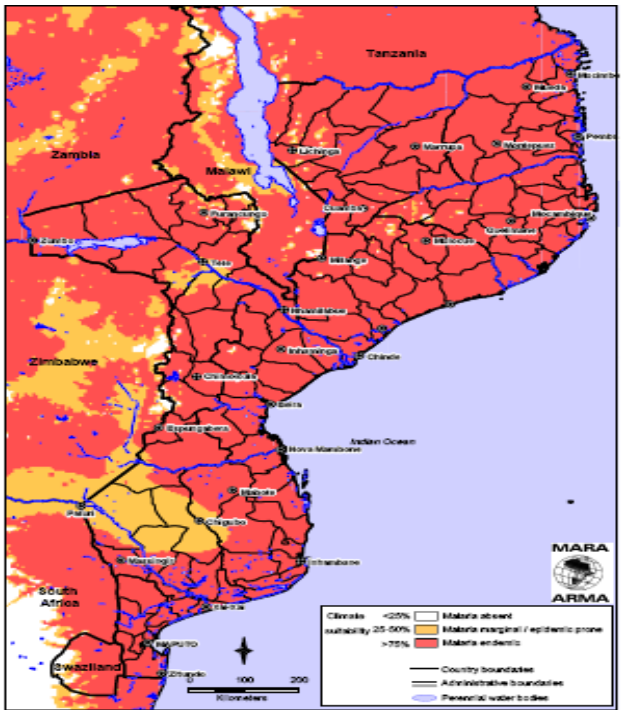
Vector control using IRS remains important in the control of local malaria transmission from imported cases in Mauritius. Although the country has the potential to eliminate malaria, the importation of cases and presence of vector mosquitoes remains a challenge. IRS using DDT will continue in harbors and the airport vicinity in order to avoid establishment of endemic malaria transmission. Capacity for malaria control including IRS is sufficient with supportive services provided by a strong entomological team and laboratories.

3.10. MOZAMBIQUE

3.10.1. Brief malaria epidemiology

Estimated population of Mozambique is about 19 000 000 all of whom are at risk of endemic malaria with perennial transmission (Fig 16). *Anopheles funestus* and *An. gambiae* s.s are the major vectors. *An. arabiensis* is an important vector in some parts of the country, such as Matola, and coastal suburbs of Maputo in southern Mozambique (Jacobsen et al. 2000). *Anopheles funestus* is resistant to pyrethroids (lambdacyhalothrin) and the carbamate propoxur (Brooke et al., 2001). The vector however is susceptible to DDT (Hargreaves et al., 2000; Brooke et al., 2001). Information on susceptibility status of *Anopheles gambiae* s.s. and *An. arabiensis* to the insecticides in use, pyrethroids, DDT and carbamate has not been accessed..

Figure 16. Malaria distribution and endemicity in Mozambique



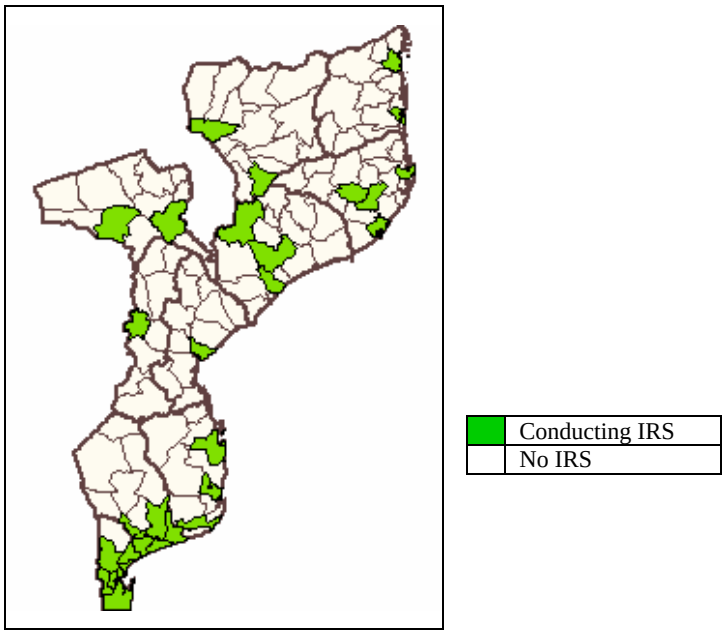
3.10.2. Implementation and management of the IRS program

Application of IRS using DDT was initiated in 1946 in peri-urban areas of Maputo city and the Limpopo Valley in southern Mozambique (Ferreira 1958 in Mabaso et al., 2004). The eradication pilot project with the application of DDT was launched in southern Mozambique during 1960 – 1969 (Schwalbach & de la Maza 1985 in Mabaso et al., 2004). The IRS program was disrupted from 1970 to the early 1990s due the unstable political situation. In the last decade the malaria control program has evolved to a point of implementing large scale IRS programs using DDT and lambdacyhalothrin in several areas in 42 districts (Fig 17) (Unpublished documents of NMCP of Mozambique, 2006).,

In addition to this national effort, the Lubombo Spatial Development Initiative (LSDI) an inter-country cross - border malaria control program is jointly implemented by Mozambique, South Africa and Swaziland. Following the agreement made by the three countries in 1999, the LSDI project commenced operations in southern Mozambique bordering the most malarious areas of South Africa and Swaziland in December 1999. IRS is the major component of the initiative. The LSDI has been spraying bendiocarb (carbamate) in the project area for the last 5 years. The project has reported reduction in malaria prevalence each year of implementation. A significant reduction in parasite prevalence among the human population, vector density and sporozoite positivity rates in *An.*

arabiensis and *An. funetus* has been documented following the launch of the comprehensive malaria control program, in which IRS is a major component (Sharp et al. 2007).

Figure 17. Districts in Mozambique conducting IRS, 2006



Policy/strategy and population coverage in 2005-2006 malaria season

Policy/ strategy	No structures targeted to be sprayed	Actual No structures sprayed	Ave. operational coverage	Population protected	Trend of population coverage
- Routine IRS to control endemic malaria transmission - In urban, per-urban & rural areas with high malaria risk	Not reported	Not reported	Not reported	- 5 700 000 (25% of the at risk)	-Increases as Government commitment strengthens and more resources are made available

Management and technical capacity

Basic documents	Planning	Spraying	Supervision	Funding
-Strategic plan available -Policy document available -National IRS guidelines available	-IRS is planed by the national and district malaria staff	-Trained spray operators from the local communities do spraying under the supervision of district health staff	-Supervisory check list available -Supervision not done regularly by national health staff except in the LSDI areas	-Government -GFATM

Monitoring and evaluation

Quality assessment with contact bioassay	Test on vector susceptibility to insecticides	IRS impact evaluation	
		Entomological indicators	Malaria burden
-WHO standard protocol and test kits available -There is trained staff -Done regularly in LSDI area	-WHO standard protocol available -A few kits available at NIH -Sentinel sites established only in LSDI areas -Trained staff available -Done regularly only in LSDI areas	-IRS impact on vector population & malaria transmission assessed through exit window trap collection & vector sporozoite positivity rate -Done only in LSDI areas	-IRS impact on malaria burden evaluated routinely only in LSDI areas

Maintenance and storage of spraying equipment

Storage capacity	Sprayers maintenance capacity
-Appropriate storage available -Storage checklist available at national & provincial levels -Health staff responsible for storage	-No checklist for cleaning, proper handling and basic maintenance of sprayers -No functional sprayer maintenance workshop -There are 12 - 15 trained staff in sprayer maintenance

Pesticide management

Regulatory legislatives	Transport & storage	Handling, application & use	Waste management
-Insecticides used for IRS registered -Importation of insecticides controlled -Information on capacity for and practices of quality control of insecticides not reported -Insecticides for IRS taxed	-No checklist on safe transportation & storage of insecticides -Appropriate storage available	-No checklist on proper handling of insecticides -Protective gear for safe handling of insecticides not used all times -Spray operators not adequately educated on occupational safety & health -Monitoring/inspection of sprayers not regularly done -Public education for safety awareness not regularly conducted	-No checklist on proper disposal of pesticide containers, spray washes & other contaminated materials -Proper & safe disposal of the above not practiced

Insecticide application in 2005-2006 malaria season

Type	Amount of formulation used (kg)	Active ingredient	Formulation
-Lambdacyhalothrin	-51 000	-10%	-WP
-Bendiocarb	-9 250	-80%	-WP
-Deltamethrin	-408	-5%	-WP
-DDT	-410 250	-75%	-WP

3.10.3. Perspectives

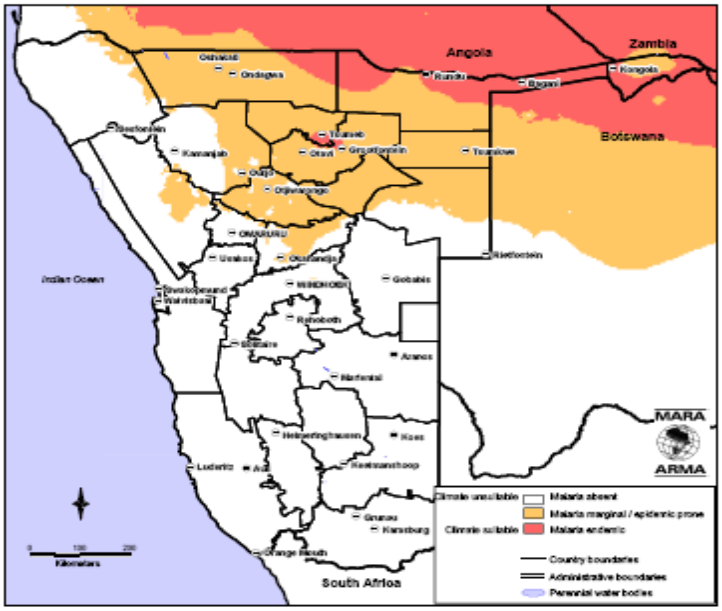
Mozambique is one of the countries in the region where IRS has significantly expanded. This is due to the growing interest to scale up malaria vector control in the country which is based on the success of the LSDI areas in southern Maputo Province. Population coverage increased from less than 5% before 2003 to about 25% in 2006. Significant reduction in malaria burden is being achieved particularly in the LSDI operational areas. Impact of the spraying on malaria burden in other areas is not yet documented. Nevertheless, NMCP needs to further build its technical and system capacity for effective implementation and management of IRS in order to increase quality and efficacy of the program outside the LDSI operational areas.

3.11. NAMIBIA

3.11.1. Brief malaria epidemiology

Estimated population of Namibia is about 2 000 000. Of these approximately 700 000 are at risk of malaria. Malaria transmission is unstable and seasonal in almost all malariaous areas of Namibia, which is mainly in the northern part (Fig 18). *Anopheles arabiensis* is the most important malaria vector following elimination of *An. funestus* and probably *An gambiae* s.s. through years of IRS application using DDT. There is no information on the existence of any subsidiary vector. *Anopheles arabiensis* is susceptible to the insecticides in use, DDT and pyrethroids (Bagayoko et al 2005).

Figure 18. Malaria distribution and endemicity in Namibia



3.11.2. Implementation and management of the IRS program

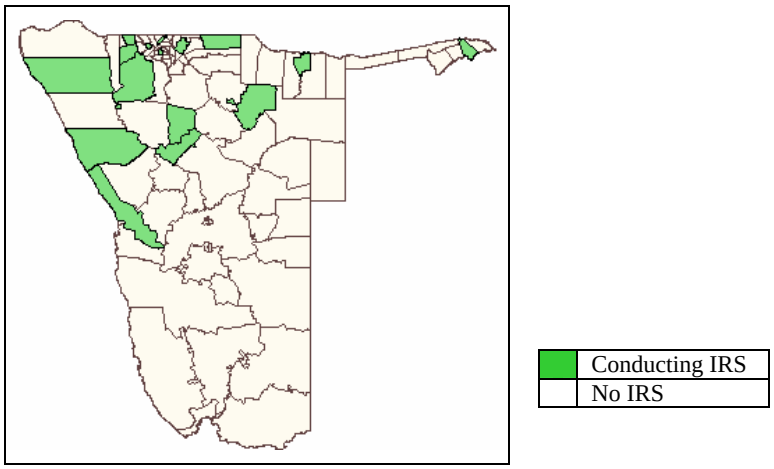
The application of IRS using DDT was first initiated in 1965 on a small scale and was followed by full coverage of all malarious districts in 1970 (Unpublished documents of NMCP, Namibia). Later on, in 1991 a broad malaria control program was commenced within the National Vector Borne Disease Control Program. Since then, IRS is applied in all malaria areas of the country. DDT is applied in traditional structures while pyrethriod is used to spray modern houses in 20 districts in 8 provinces (Fig 19). WHO has worked closely with the NMCP to address the persistent problems associated with quality and timeliness in relation to transmission season observed in the late 1990s and early 2000s. The program has shown progressive changes and improved operational coverage and quality of spraying during the last 3-4 years (Table 4). Information on the current capacity and system of IRS programs is summarized below.

Table 4. Progressive coverage of the IRS program in Namibia, 2004/5- 2006/7

Administrative region	2004-2005		2005-2006		2006-2007	
	% population protected	Operational coverage	% population protected	Operational coverage	% population protected	Operational coverage
Ohangwena	44.3	78.9	44.6	82	81.9	94.6
Kavango	84	71.6	83.4	80	96.1	93
Kunene	43	83	43.5	61.4	50.2	83
Otjozondjupa	--	92	--	93.9	89.7	73
Omusari	35.4	60.6	60.7	89.7	70.9	90
Oshikoto	50.8	50.4	80.3	98.2	92.7	73
Oshana	89.4	56	63	57.7	84.2	79
Caprivi	98.8	81.4	--	80.3	70.4	87
Namibia	**55.7**	**69.2**	**59.8**	**82**	**77**	**86.6**

-- No information

Figure 19. Districts in Namibia conducting IRS, 2007



Policy/strategy and population coverage in 2006-2007 malaria season

Policy/ strategy	No structures targeted for spraying	Actual No structures sprayed	Ave. operational coverage	Population protected	Trend of pop. coverage
-Routine IRS for epidemic prevention and control -Mainly in per-urban and rural areas	Not reported	Not reported	86%	-400 000 (77% of at risk of malaria)	-More or less similar during the last few years

Management and technical capacity

Basic documents	Planning	Spraying	Supervision	Funding
-Strategic plan available -There is national IRS guideline	-IRS is planed by the regional & district malaria staff	-Trained spray operators from the local communities do spraying under the supervision of district health staff	-Supervisory check list available -Supervision not done regularly by national and regional health staff	-MOH

Monitoring and evaluation

Quality assessment with contact bioassay	Test on vector susceptibility to insecticides	IRS impact evaluation	
		Entomological indicators	Malaria burden
-WHO standard protocol and test kits available -There is one trained staff -Done annually	-WHO standard protocol and test kits available -Sentinel sites established -Trained staff available -Tests done once every 2 years	-IRS impact on vector population density and sporozoite positivity rate not assessed	-IRS impact on malaria burden not evaluated

Maintenance and storage of spraying equipment

Storage capacity	Sprayers maintenance capacity
-No appropriate storage facilities -Storage checklist not available -Regional chief health inspectors are responsible for storage of sprayers	-Checklist for cleaning, proper handling and basic maintenance of sprayers available -No functional sprayer maintenance workshop -61 staff trained in basic sprayer maintenance available

Pesticide management

Regulatory legislatives	Transport & storage	Handling, application & use	Waste management
-Insecticides used for IRS registered -Information on capacity for and practices of quality control not reported -Insecticides for IRS taxed	-Checklist on safe transportation & storage of insecticides available -No appropriate storage	-Checklist on proper handling of insecticides available -Protective gear for safe handling of insecticides not used all times -Spray operators not adequately educated on occupational safety & health -Monitoring/inspection of sprayers not regularly done -Public education for safety awareness not regularly conducted	-No checklist on proper disposal of pesticide containers, spray washes & other contaminated materials - Proper & safe disposal of the above not practiced at all times

Insecticide application in 2006-2007 malaria season

Type	Amount of formulation used (kg)	Active ingredient	Formulation
-Deltamethrin -DDT	-2 741 kg -52 815 kg	-5% -75%	-WP -WP

3.11.3. Perspectives

The IRS program in Namibia has gone through various developments through the years. The chronic problem of quality and low coverage has been resolved through persistent efforts including training of staff and improving supervision quality. Area of IRS implementation and population coverage has been more or less the same. Unlike in many of the countries in the sub-region, impact of IRS on malaria transmission and burden is not regularly assessed and reported and this needs to be strengthened in order to facilitate informed decision and program planning.

3.12. SAO TOME & PRINCIPE

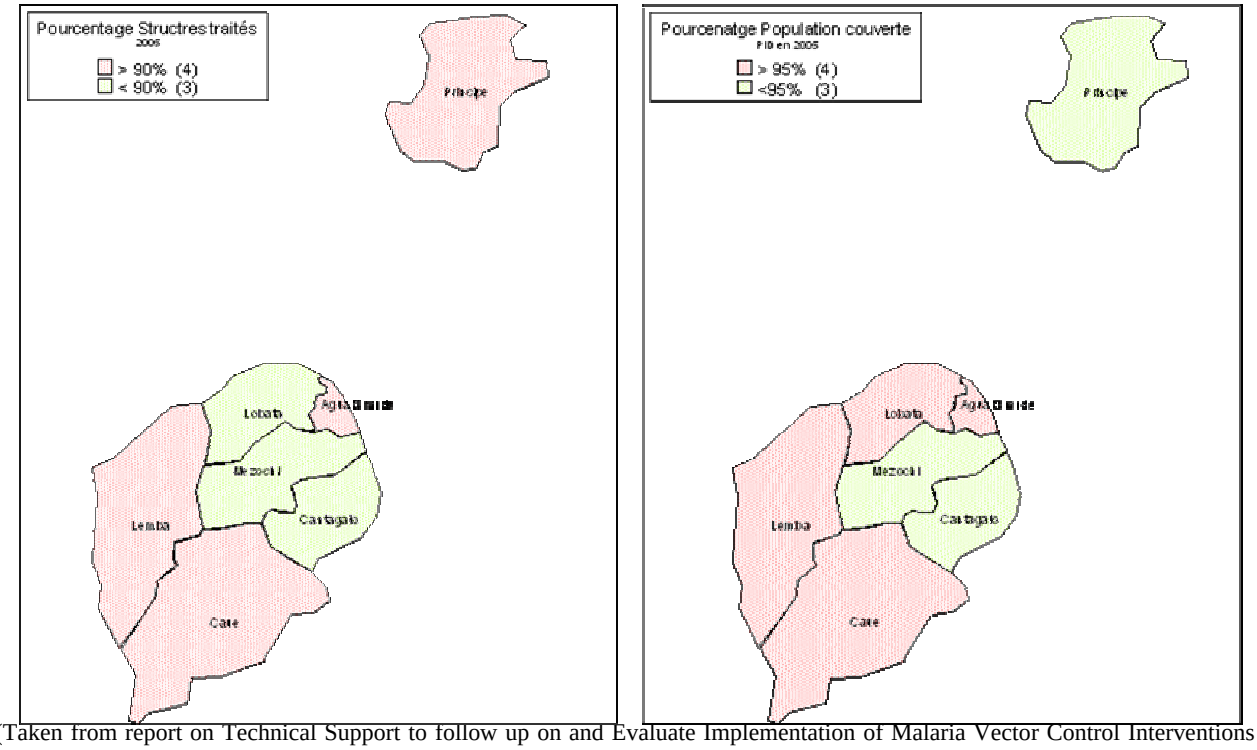
3.12.1. Brief malaria epidemiology

Sao Tome & Principe (STP) is a country with a total inhabitants of 150 000. Basically, the total population of the island is at risk of malaria infection. Malaria transmission in the two islands of STP varies. Malaria in Sao Tome is highly endemic (intense transmission) and Principe experiences moderately intense transmission but not as such unstable nature. *Anopheles gambiae* s.s is the only important malaria vector in STP where it is primarily anthropophilic with an opportunistic tendency to zoophilly and exophagy (Teklehaimanot, 2003). The species is resistant to DDT but susceptible to pyrethroids. *Anopheles pharoensis* and *An. paludis* have also been documented in the island (http://www.afro.who.int/malaria/country-profile/sao-tome.pdf, accessed on 13 Feb 2007), but their role in malaria transmission is not determined. Susceptibility tests on alphacypermethrin, carried out using the CDC bottle test, revealed a 100% mortality rate of *An. gambiae s.l.* after 60 minutes of exposure time.

3.12.2. Implementation and management of the IRS program

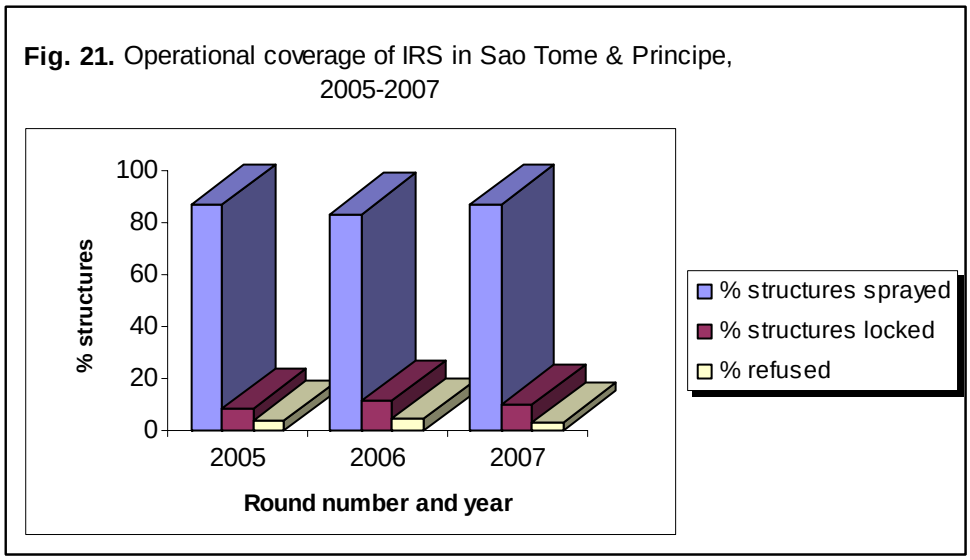
IRS was first introduced in 1980 using DDT and successfully continued until 1983. In 1984, the intervention was terminated resulting in severe epidemics in 1985-1986. Since then, until very recently the use of ITNs was the single malaria prevention method used in STP. In 2003, however, the NMCP in collaboration with Taiwanese Cooperation initiated an integrated vector management program in 5 pilot districts. The interventions included IRS, space-spraying during night time and larviciding using *Bacillus thuringiensis* var israelensis (Bti). At the end of the pilot project in 2004, the Ministry of Health decided to scale up IRS and expand its implementation to the entire country. Following this decision, a national IRS program was launched in December 2004 with a blanket spraying approach.

Figure 20. Operational coverage (a) and proportion of population protected (b) in STP in 2005

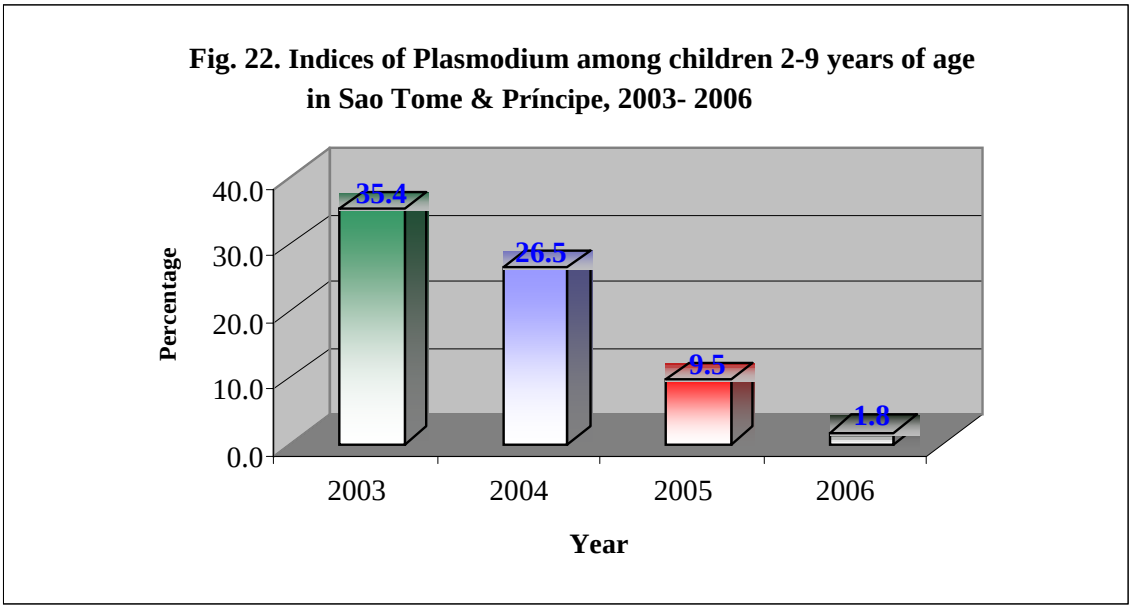


(Taken from report on Technical Support to follow up on and Evaluate Implementation of Malaria Vector Control Interventions in Sao Tome & Principle, 2005, By Dr M. Bagayoko, WHO/IST/WA)

All districts of the country (Fig 20) were sprayed with alphacypermethrin at a dose of 50mg/m^2 once a year protecting about 94% of the population. Figure 21 shows operational coverage achieved in the last three years, i.e. 2005-2007. The continuous and blanket spraying together with other malaria control interventions has resulted in reduction of malaria burden, which is depicted with the progressive reduction of Plasmodium positivity rate in children 2 - 9 years of age (Fig 22). The program is anticipated to continue until 2008 when the support from the Taiwanese cooperation is expected to terminate. Contact bioassays carried out by the Taiwanese team showed a 100% mortality of mosquito samples exposed to surfaces that were sprayed 11 months earlier. However this mortality rate was not evenly distributed on the same sprayed surface.



(Quoted from presentation by NMCP of STP on the Annual Review and Planning meeting of Central Africa malaria Control, WHO, 8-11 October 2007)



(Quoted from presentation by NMCP of STP on the Annual Review and Planning meeting of Central Africa malaria Control, WHO, 8-11 October 2007)

Policy/strategy and population coverage in 2005[14]

Policy/ strategy	No structures targeted for spraying	Actual No structures sprayed	Ave. operational coverage	Population protected	Trend of pop. coverage
-Routine IRS for the prevention and control of endemic & epidemic malaria -In urban, per-urban & rural areas	36 697	34 536 structures sprayed	87%	148 968 (98% of at risk population)	Population coverage has significantly increased

Pesticide management

Regulatory legislatives	Transport & storage	Handling, application & use	Waste management
-Insecticides used for IRS registered -Importation of insecticides controlled -Quality of insecticides checked -Insecticides for IRS taxed	-No checklist on safe transportation & storage of insecticides -Appropriate storage available	-Checklist on proper handling of insecticides not available -Protective gear for safe handling of insecticides not used at all times -Spray operators inadequately educated on occupational safety & health -Monitoring/inspection of sprayers not regularly done -Public education for safety awareness not regularly conducted	-No checklist on proper disposal of pesticide containers, spray washes & other contaminated materials - Proper & safe disposal of the above not practiced at all times

Insecticide application in 2005

Type	Amount of formulation used (kg)	Active ingredient	Formulation
Alphacypermethrin	4500	5%	WP

3.12.3. Perspectives

Sao Tome & Principe is one of the few countries where multiple vector control interventions are applied within the context of IVM. Both the two major malaria control interventions and supplementary methods such as larval control are concurrently practice. However, we do not have information on existing technical, management and monitoring and evaluation capacity and practice of the IRS program.

[14] Detailed information on implementation of IRS in 2006-2007 has not been reported

3.13. SOUTH AFRICA

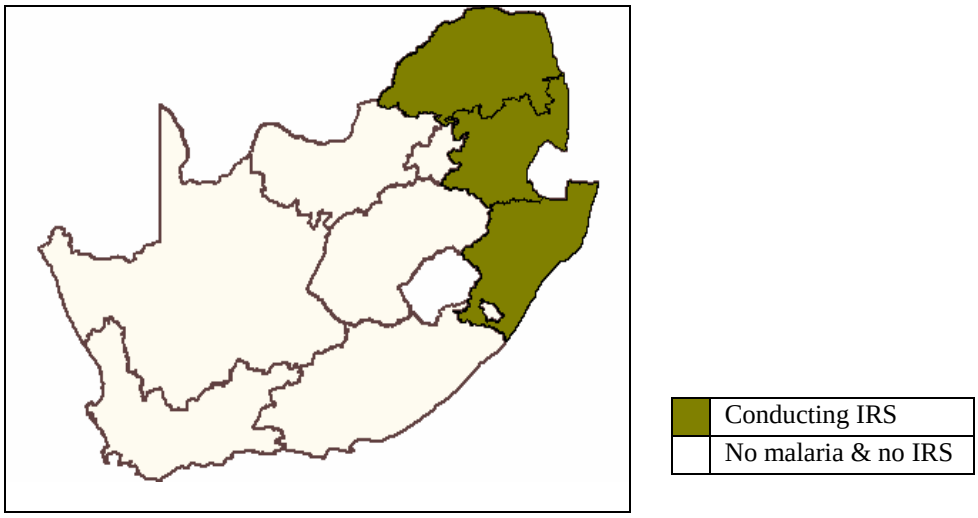
3.13.1. Brief malaria epidemiology

South Africa has a population of 45 000 000 of which 4 524 441 are at risk of malaria infection. Malaria is endemic in three provinces in the north east of the country. Transmission is unstable and seasonal in almost all malarious areas of South Africa. Currently *Anopheles arabiensis* is the only vector. *Anopheles merus* is found in abundance in some areas but has not been implicated in transmission despite the fact that it plays a significant role in other countries of its distribution. *Anopheles funestus* used to be a very important vector before it was eliminated through years of IRS with DDT. Recently, the vector re-appeared following the replacement of DDT by pyrethroids in 1996, to which *An. funestus* was resistant (Hargreaves et al., 2000). This necessitated the reintroduction of DDT in 2000 which eliminated the vector. No record of its presence was made since the re-introduction of DDT. Later on, DDT resistance was identified in a population of *An. arabiensis* in two localities in KwaZulu Natal (Hargreaves et al., 2003). However, subsequent follow ups were not able to confirm the reported resistance in the same populations.

3.13.2. Implementation and management of the IRS program

Application of IRS for malaria control in South Africa goes back to 1932 following a trial test that was carried out in 1931 in KwaZulu-Natal using pyrethrum (Park Ross 1936; De Meillon 1936; Mabaso et al., 2004). Application of pyrethrum was replaced by DDT in 1946 (Sharp et al., 1988; le Sueur et al., 1993). In 1958 a total coverage of all the population at risk of transmission was achieved and in 1970 a comprehensive malaria control program was launched (Sharp & Le Sueur 1996). Application of DDT continued until 1996 when a pyrethriod (deltamethrin) was introduced as the insecticide of choice. The application of only pyrethroids continued until 2000 when high malaria transmission of epidemic proportion was reported due to the emergence of a pyrethroid resistant *An. funestus* population (Hargreaves et al., 2000).

Figure 23. Provinces in South Africa conducting IRS, 2006



To date, South Africa uses DDT in traditional houses and pyrethroids in western-style houses for malaria vector control and eight districts are protected in three malarious provinces (Limpopo, Mpumalanga & KwaZulu-Natal) (Fig 23) (Report of NMCP, 2006). In 2005, bendiocarb was tried in KwaZulu-Natal province but was not continued due to its high cost. South Africa is one of the three collaborating countries in the implementation of the LSDI initiative for malaria control where IRS is the major intervention. The geographical area of spraying in South Africa is decreasing while population protected is increasing. This has been attributed to increased cross-

border movement of people from the malaria areas of southern Mozambique into settlements on the South African side of the border.

Policy/strategy and population coverage in 2005-2006 malaria season

Policy/ strategy	No. structures targeted for spraying	No. structures sprayed	Ave. operational coverage	Population protected	Trend of pop. coverage
- Routine IRS for epidemic prevention and control - Mainly in rural areas	1 873 494	1 555 000 structures sprayed	83%	4 220 000 (75% of the population at risk)	Area of spraying decreased but number of people protected increased

Management and technical capacity

Basic documents	Planning	Spraying	Supervision	Funds
-IRS strategic plan available -National IRS guideline available	-IRS is planed by the province & district health staff	-Spraying is carried out by trained district health staff	-Supervisory check list available -Supervision done regularly by provincial staff	-MOH

Monitoring and evaluation

Quality assessment with contact bioassay	Test on vector susceptibility to insecticides	IRS impact evaluation	
		Entomological indicators	Malaria burden
-WHO standard protocol and test kits available -There are 4 trained staff at provincial level -Done twice a year	-WHO standard protocol and test kits available -There are established sentinel sites -4 trained staff available (same) -Tests done randomly	-IRS impact on vector population density is monitored by exit window traps & pyrethrum spray collection	-IRS impact on malaria burden is continuously evaluated

Maintenance and storage of spraying equipment

Storage capacity	Sprayers maintenance capacity
-Appropriate storage facility available -Storage checklist available at all levels -Provincial MCPs are responsible for storage of sprayers	-Checklist for cleaning, proper handling and basic maintenance of sprayers available -There is functional sprayer maintenance workshop -All spraying staff do general sprayer maintenance & 15 are trained in specialized repairs

Pesticide management

Regulatory legislatives	Transport & storage	Handling, application & use	Waste management
-Insecticides used for IRS registered -Importation of insecticides controlled -Quality of insecticides checked -Insecticides for IRS taxed	-Checklist on safe transportation & storage of insecticides available -Appropriate storage available	-There is checklist on proper handling of insecticides -Protective gear for safe handling of insecticides used all times -Spray operators adequately educated on occupational safety & health -Monitoring/inspection of sprayers regularly done -Public education on safety awareness not regularly conducted	-Checklist on proper disposal of insecticide containers, spray washes & other contaminated materials available -Proper & safe disposal of the above is practiced

Insecticide application in 2005-2006 malaria season

Type	Amount of formulation used (kg)	Active ingredient	Formulation
-Deltamethrin -DDT -Alphacypermethrin	-4 766 kg -87 433 kg -890 kg	-5% -75% -6%	-WP -WP -SC

3.13.3. Perspectives

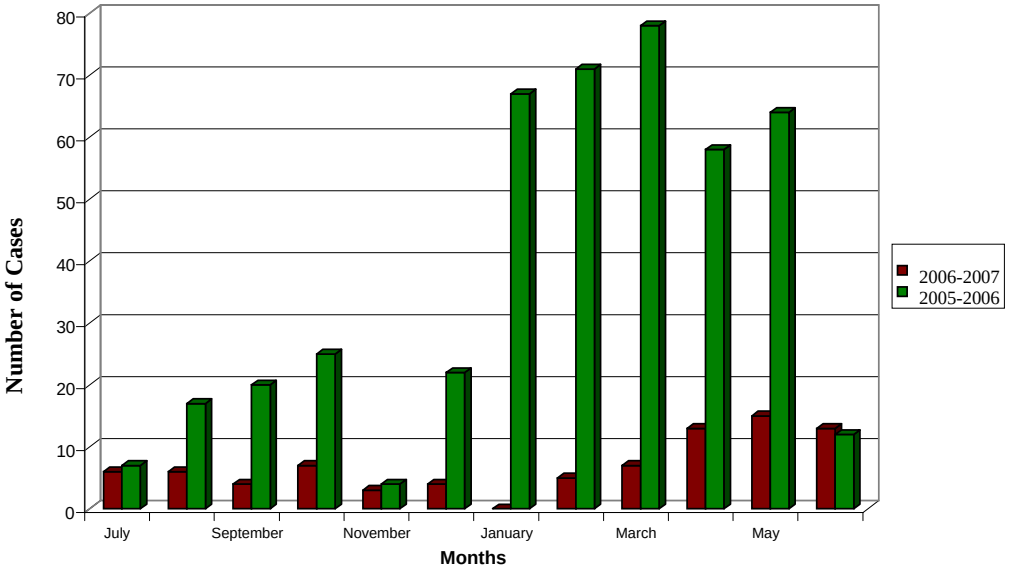
Indoor residual spraying in South Africa remains the cornerstone of the malaria control program and has significantly impacted on malaria transmission through the years. The geographical extent and intensity of transmission of the disease has been greatly reduced. As distribution of malaria declines, so the area of IRS implementation has been decreasing. However, recently increased population coverage has been reported as a result of cross-border population movements from Mozambique, which has increased population size in the IRS implementation areas. This emphasizes the fact that further success in reduction or even elimination of malaria in South Africa might be difficult without similar successes in the neighboring counties. In cognizance of this factor, South Africa has now developed a strategic plan to eliminate malaria mainly with the application of IRS by involving neighboring countries in the program including Zimbabwe, Swaziland and Mozambique. With the development of cross border collaboration, the IRS program of South Africa is expected to continue contributing to strengthening control programs in the neighboring countries. The IRS program in South Africa has a history of practicing good management and monitoring systems. Capacity for IRS is sufficient at all levels.

3.14. SWAZILAND

3.14.1. Brief epidemiology of malaria

An estimated population of 1 200 000 live in the Kingdom of Swaziland, out of which about 400 000 are at risk of malaria infection. Malaria transmission in Swaziland is seasonal and unstable (Fig 24) and epidemics are very common during years of favorable climatic conditions for vector breeding and population expansion. The country has a well managed and successful malaria control program with IRS at the center of the strategy. In recent years, the program has been reporting a significant reduction in malaria burden (Fig. 25) following an intensive application of IRS in all malarious areas (Fig 26). *Anopheles arabiensis* is the principal vector. *Anopheles funestus* used to play a role before its elimination due to the intensive application of IRS. It has not been detected in the country for many years even in areas bordering with Mozambique where the species is still a very important vector. *Anopheles arabiensis* is susceptible to DDT and pyrethroids.

Fig. 24. Laboratory confirmed malaria cases by transmission season (2005-2006) and (2006-2007)

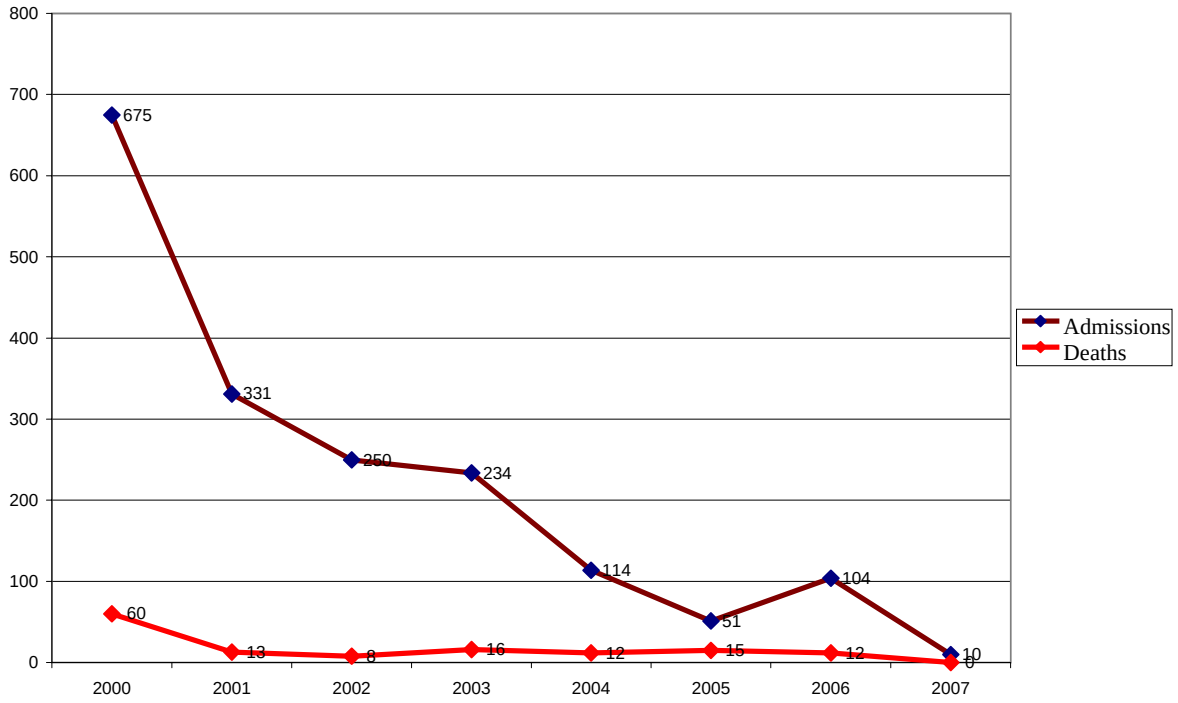


(Taken from report of NMCP of Swaziland, 2007)

3.14.2. Implementation and management of the IRS program

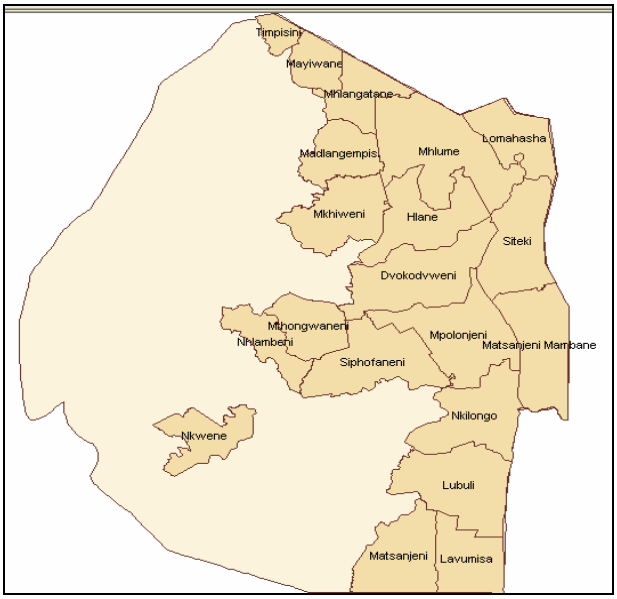
Indoor residual spraying for malaria control was first initiated in 1947 following the launch of a malaria control program in 1945 (Mastbaum 1954, 1955, 1956, reviewed in Mabaso et al., 2004). Coverage of all malarious areas by IRS using DDT was already achieved by 1950 and in 1951-1952 BHC was introduced due to shortage of DDT (Mabaso et al., 2004). Between 1952 and the 1980s application of both BHC and DDT continued in different places. From the 1980s onwards only DDT became the insecticide of choice and since the 1990s the application of pyrethroids for spraying of modern houses has been practiced. Swaziland is one of the participating countries in the LSDI initiative. To date 20 Tinkhundlas (districts) in all four regions are covered by the spraying program (Fig 26).

Figure. 25. Hospital admissions and deaths due to malaria in Swaziland, 2000-2007*



*Inpatient information from Goodshepherd Hospital, taken from report of NMCP of Swaziland, 2006-2007

Figure 26. Map of Swaziland showing 20 districts covered by IRS, 2007



(Taken from report of NMCP of Swaziland, 2006-2007)

Policy/strategy and population coverage in 2006-2007 malaria season

Policy/ strategy	No. structures targeted for sprayed	No. structures actually sprayed	Ave. operational coverage	Population protected	Trend of population coverage
-Routine IRS to control seasonal transmission -In response to epidemics if any -Primarily in rural & peri-urban areas	-99 700 -20 700	-72 338 -20 039	- 91.3% for DDT - 97% for pyrethroid	- 400 000 (80% of at risk population)	-Population coverage is expected to decrease as malaria transmission declines

Management and technical capacity

Basic documents	Planning	Spraying	Supervision	Funding
-There is IRS strategic plan -National IRS guideline available	-IRS planed by national, province & district staff	-Spraying carried out by trained spray operators supervised by district health staff	-Supervisory check list available -Supervision done monthly by national & district supervisors during spraying	-MOH

Monitoring and evaluation

Quality assessment with contact bioassay	Test on vector susceptibility to insecticides	IRS impact evaluation	
		Entomological indicators	Malaria burden
-WHO standard protocol and test kits available -Trained staff available -Done monthly during spraying	-WHO standard protocol & test kits available -There are 4 sentinel sites -Trained staff available -Tests done randomly	-Impact of IRS on the vector population density assessed using PSCs	-Impact of IRS on malaria burden evaluated

Maintenance and storage of spraying equipment

Storage capacity	Sprayers maintenance capacity
-Appropriate storage available (districts) -Storage checklist available -3 technicians responsible for storage of sprayers	-Checklist for cleaning, proper handling and basic maintenance of sprayers available -There is functional sprayer maintenance workshop -Supervisors trained in sprayer maintenance & spray operators trained in very basic maintenance while trained in spraying

Pesticide management

Regulatory legislatives	Transport & storage	Handling, application & use	Waste management
-Insecticides used for IRS registered -Importation of insecticides controlled -Quality of insecticides checked -Insecticides for IRS not taxed	-Checklist on safe transportation & storage of insecticides available -Appropriate storage available	-Checklist on proper handling of insecticides available -Protective gear for safe handling of insecticides used all times -Spray operators adequately educated in occupational safety & health -Monitoring/inspection of sprayers regularly done -Public education on safety awareness not conducted regularly	-Checklist on proper disposal of insecticide containers, spray washes & other contaminated materials available -Proper & safe disposal of the above practiced

Insecticide application in 2006-2007 malaria season

Type	Amount of formulation used (kg)	Active ingredient	Formulation
-DDT -Deltamethrin	-10 050 -257	-75% -5%	-WP -WP

14.3. Perspectives

The IRS program in Swaziland has good technical and systemic capacity and is well managed. Malaria transmission is diminishing through a comprehensive malaria control strategy with IRS as a major component. It has been indicated that spraying will remain widely used for sometime in the future to consolidate what has been achieved. Currently, the program is moving towards elimination alongside of South Africa.

3.15. TANZANIA (ZANZIBAR)

3.15.1. Brief malaria epidemiology

Zanzibar Island is inhabited by a population of about 1 200 000 and all are at risk of malaria infection. Transmission on the island is perennial and stable. *Anopheles gambiae* s.s. and *An. funestus* are the main vector with *An. merus* playing a secondary role. *Anopheles gambiae* s.s. is susceptible to the insecticide in use, the pyrethroid Lambda-cyhalothrin. No information is currently available on the susceptibility status of the vectors to DDT and other public health pesticides. However, it should be noted that DDT resistance of *An.gambiae* was recorded in Zanzibar in the 1980s and became one of the reasons to abandon the IRS program.

3.15.2. Implementation and management of the IRS program

Zanzibar Island runs an independent malaria control program which promotes a different strategy from that of the mainland. Indoor residual spraying in Zanzibar was first initiated in the 1950s. But it was interrupted from 1958 to 1965 due to policy change. It was reinitiated in 1966 and was again ceased in 1987 due to lack of funds and appearance of vector resistance to DDT which caused program failure (Ministry of Health, Zanzibar). Since then malaria control efforts have concentrated on case management and later on ITN promotion. However, in 2006 IRS was re-introduced in a large scale campaign with financial support from PMI. Two rounds of spraying with lambdacyhalothrin have been implemented in all 10 districts of the island with a reportedly dramatic impact on malaria transmission and burden (Unpublished documents of Ministry of Health, Zanzibar). About 1.1 million (86%) of the total population is protected. The PMI funded spraying campaign is expected to continue for the coming five years.

Policy/strategy and population coverage in 2005-2006 season

Policy/ strategy	No. structures targeted to be sprayed	No. structured sprayed	Ave. operational coverage	Population protected	Trend of pop. coverage
-Routine IRS to control perennial transmission -The whole country is sprayed	197 328	189 435	96%	1 081 156 people	Population coverage is expected to remain more or less the same in the coming few years

Management and technical capacity

Basic documents	Planning	Spraying	Supervision	Funding
-IRS strategic plan available -National IRS guideline available	-IRS planed by the national & district staff with support from RTI (contractor of PMI) & WHO	-Spraying carried out by RTI in collaboration with the district health staff	-Supervisory check list available -Supervision done regularly by national & district supervisors	-MOH -PMI (USAID)

Monitoring and evaluation

Quality assessment with contact bioassay	Test on vector susceptibility to insecticides	IRS impact evaluation	
		Entomological indicators	Malaria burden
-WHO standard protocol and test kits available -Trained staff available -Done monthly after spraying	-WHO standard protocol and test kits available -Sentinel sites established -Trained staff available -Tests done once in two years	-Impact of IRS on the vector population density and sporozoite positivity rate not assessed	-Impact of IRS on malaria burden evaluated

Maintenance and storage of spraying equipment

Storage capacity	Sprayers maintenance capacity
-Appropriate storage available -Storage checklist available at all levels -Appointed logistician responsible for storage of sprayers	-Checklist for cleaning, proper handling and basic maintenance of sprayers available -There is functional sprayer maintenance workshop -There are 7 staff trained in sprayer maintenance

Pesticide management

Regulatory legislatives	Transport & storage	Handling, application & use	Waste management
-Insecticides used for IRS registered -Information on capacity for and practices of quality control of insecticides not reported -Insecticides for IRS taxed	-Checklist on safe transportation & storage of insecticides available -Appropriate storage available	-Checklist on proper handling of insecticides available -Protective gear for safe handling of insecticides used all times -Spray men adequately educated on occupational safety & health -Monitoring/inspection of sprayers regularly done -Public education on safety awareness not conducted regularly	-No checklist on proper disposal of insecticide container, spray washes & other contaminated materials -But proper & safe disposal of the above practiced in most cases

Insecticide application in 2005-2006 season

Type	Amount of formulation used (kg)*	Active ingredient	Formulation
Lambdacyhalothrine	592	10%	WP

* There is a discrepancy between the reported sprayed number of structures and the amount of insecticide used. One would expect to spray only 47 360 structures with this amount of insecticide not 190 000.

3.15.3. Perspectives

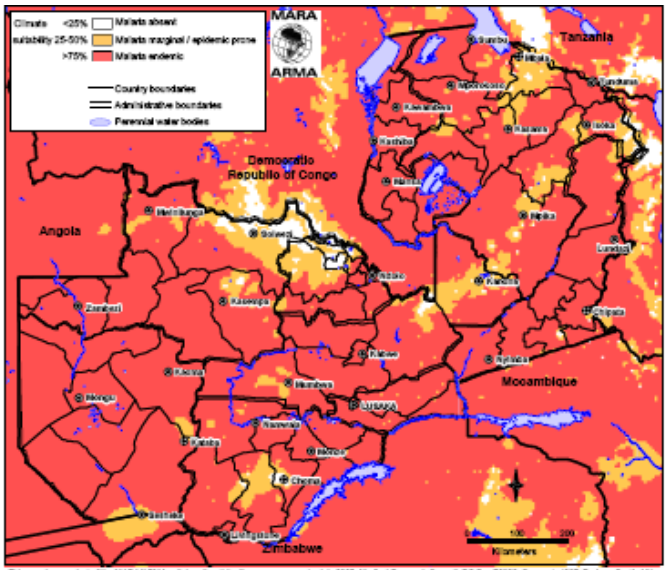
Indoor residual spraying in Zanzibar had been initiated and interrupted a number of times in the last 50 years. Similar to all the previous efforts the current IRS campaign has achieved a dramatic impact on malaria burden. However, being fully partner-funded, to devise a strategy to sustain the gains made against malaria when donor support ceases is critical in the coming few years. Depending on the level of malaria transmission reduction that would be achieved by the end of the current project, gradual replacement of IRS by a high coverage of LLINs might be the way forward in order not to repeat the same post-campaign experiences of malaria resurgence that took place on the island.

3.16. ZAMBIA

3.16.1. Brief epidemiology of malaria

Zambia has a total population of 11 000 000. Basically, the whole population is at risk of malaria infection (Fig 27). Transmission is perennial in hot riverine valleys where malaria is highly endemic while intensity of transmission is moderate to high on the plateaus. The most important malaria vectors in Zambia are *An. gambiae* s.s., *An. arabiensis* and *An. funestsus.* All the three vectors are susceptible to DDT and pyrethroids (Bagayoko, et al. 2005)

Figure 27. Malaria distribution and endemicity in Zambia



3.16.2. Implementation and management of the IRS program

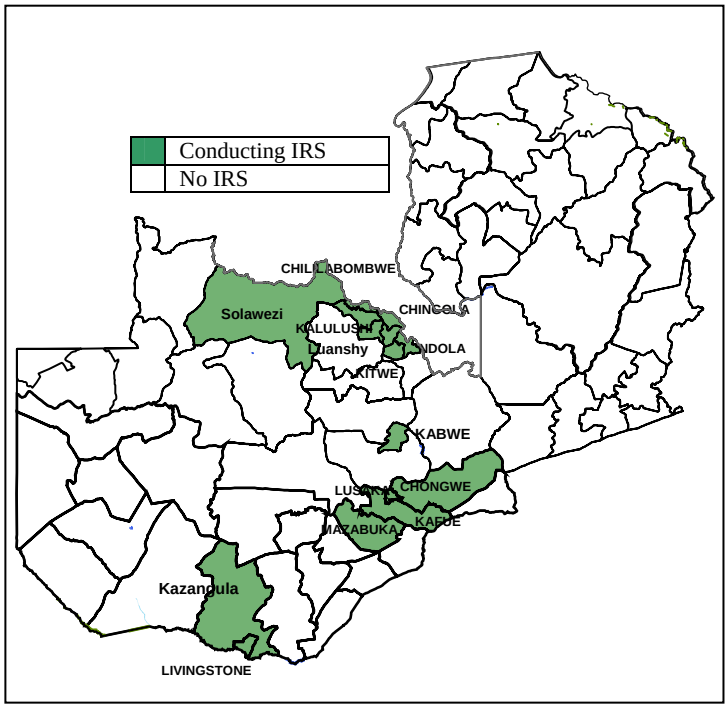
Malaria prevention and control in the copper mining towns of Zambia has a long history of IRS. Utzinger et al. (2002) refers to early economic payoffs of malaria control activities between 1930 and 1950 that were carried out in the copper belt communities. Early malaria prevention and control efforts in these areas had a stronger emphasis on environmental management, combined with diagnosis and treatment of malaria cases**.** Copper deposits and favorable climate increased investments and therefore attracted many settlers, and made the copper mining towns highly urbanized and economically developed. As urbanization emerged, the municipal town planners took malaria control into consideration. Notable among their actions was the introduction of the statutory instrument referred to as the Mosquito Extermination Act of 1944**,** whose goal was primarily to improve hygienic measures. However, amendment of the Act in 1964 obliged each household to stop mosquito breeding in their immediate environment by requiring mining companies, irrigation and water supply works to take specific measures**.**

By the 1950s national health authorities in Zambia adopted IRS in urban communities, including the copper mining areas. Implementation of IRS in the target urban centers progressed well until Zambia started experiencing economic decline. After 1976 the decline in copper prices together with the ban of DDT for agricultural use led to unavailability of affordable and effective insecticides and negatively affected Zambia's NMCP. Thus, by 1980, the IRS coverage was reduced markedly and finally stopped altogether. The National Malaria Control Strategy covering the period 2001-2005 which emphasized prevention focused on the need for developing a targeted vector control strategy in the context of IVM.

The main interventions under the IVM strategy are IRS and Insecticide Treated Nets (ITNs) implemented in eligible urban and rural areas respectively. Larviciding and simple environmental management (canalization,

draining and land filling) are implemented in collaboration with the local authorities and communities as supplementary interventions in urban areas during the dry season when the breeding sites for *Anopheles* vectors are discreet and accessible. IRS is implemented to control perennial and seasonal transmission and also epidemics. In 2004, a total of 324 137 people were protected by IRS. Since then, the intervention has been expanding into new areas and more at risk people are protected (Ministry of Health, Zambia 2006). In 2005, localities in 8 districts were sprayed. In 2006 Zambia expanded spraying to cover 15 districts (Fig 28) using both DDT and pyrethroids. IRS is done both by the public and the private sectors. The private sector focuses in areas of economic interest such as the copper belt.

Figure 28. Districts in Zambia conducting IRS, 2007 (NMCP of Zambia)



Policy/strategy and population coverage in 2006 – 2007 malaria season

Policy/ strategy	No structures targeted to be sprayed	No. structure sprayed	Ave. operational coverage	Population protected	Trend of pop coverage
-Routine IRS to control perennial & seasonal transmission -Primarily in urban & peri-urban	-281 489	-236 759	84%	-1 200 000 (45% of the at risk population)	-Population coverage is expected to increase due to program expansion

Management and technical capacity

Basic documents	Planning	Spraying	Supervision	Funding
-IRS strategic plan available -National IRS guideline available	-IRS planed by the national & district health staff -No information on the collaboration with the private sector in planning	-Carried out by trained spray operators under the supervision of DHMTs -Also conducted by mining companies	-Supervisory check list available -Done regularly by national & district supervisors	-Government -GFATM -Mining companies -USAID

Monitoring and evaluation

Quality assessment with contact bioassay	Test on vector susceptibility to insecticides	IRS impact evaluation	
		Entomological indicators	Malaria burden
-WHO standard protocol and test kits available -Conducted routinely after spraying	-WHO standard protocol and test kits available -No established sentinel sites -Trained staff available -Tests done every year at different sites	-Impact on vector populations density assessed through PSC	-Impact on malaria burden has been evaluation by MASEPA in some areas

Maintenance and storage of spraying equipment

Storage capacity	Sprayers maintenance capacity
-Appropriate storage facilities available -Storage checklist available -Municipalities responsible for storage of sprayers	-Checklist for cleaning, proper handling and basic maintenance of sprayers available -There is functional sprayer maintenance workshop -No information if staff trained in sprayer maintenance available

Pesticide management system

Regulatory legislatives	Transport & storage	Handling, application & use	Waste management
-Insecticides used for IRS registered by ECZ -Importation of insecticides controlled by ECZ -Quality of insecticides checked by ECZ -Insecticides for IRS taxed	-No checklist on safe transportation & storage of insecticides -Appropriate storage available	-No checklist on proper handling of insecticides -Protective gear for safe handling of insecticides used in most cases -Spray operators not adequately educated on occupational safety & health -Monitoring/inspection of sprayers not regularly done -Public education on safety awareness not regularly conducted	-Checklist on proper disposal of pesticide containers, spray washes & other contaminated materials available -Proper & safe disposal of the above in most cases practiced

Insecticide application in 2006-2007 malaria season

Type	Amount of formulation used* (kg)*	Active ingredient	Formulation
-DDT -Alphacypermethrin -Lambdacyhalothrin	-28 875 kg -7 350 kg -4 125 kg	-75% - 5% - 10%	-WP -WP - WP

* There is a discrepancy between the reported sprayed number of structures and the amount of insecticide used. One would expect to spray 798 000 structures with this amount of insecticide not only 236 759 structures.

3.16.3. Perspectives

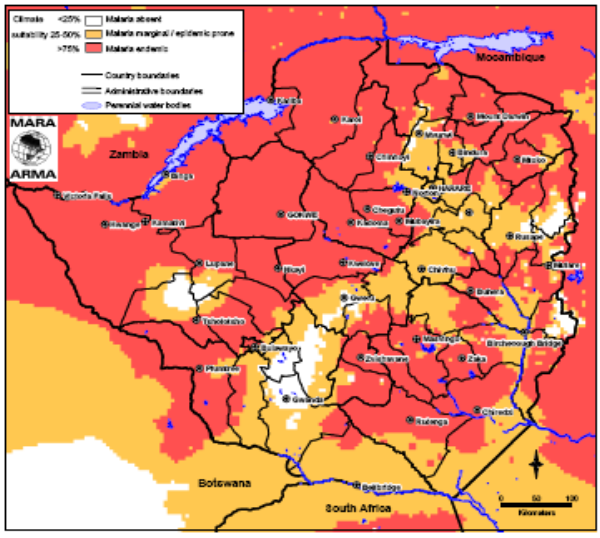
Zambia is one of the few countries where the two major vector control interventions, ITNs and IRS, are concurrently being scaled up within the context of IVM. Since 2004, IRS population coverage has increased by more than 100% (324 137 & 772 644 people protected in 2004 & in 2005 respectively). In 2006, the number increased to more than a million. The trend is expected to continue in the near future. The country has been building its capacity to ensure effective implementation of IRS. It also has received significant support from WHO in the area of technical capacity building for planning, implementation, monitoring and evaluation of the program. There is a relatively good technical capacity and management system.

3.17. ZIMBABWE

3.17.1. Brief malaria epidemiology

Zimbabwe has an estimated population of 12 000 000 of which 5 500 000 are at risk of malaria. Most malarious areas of Zimbabwe experience seasonal transmission with a risk of epidemics. Perennial malaria transmission exists in lowland areas particularly in major river basins (Fig 29). *Anopheles arabiensis* is the main vector of malaria in Zimbabwe after *An. funestus* was eliminated through years of IRS application. *Anopheles gambiae s.s.* has been recorded in recent times from the Zambezi Valley (Masendu et al., 2004) but in very small numbers and no information is available on its role in malaria transmission in this locality. *Anopheles merus* is commonly found in some parts of the country particularly in Gokwe district but no information is yet available on its role in malaria transmission (Masendu et al., 2005). *Anopheles arabiensis* is resistant to deildrin but susceptible to pyrethroids and DDT (Bagayoko et al. 2005).

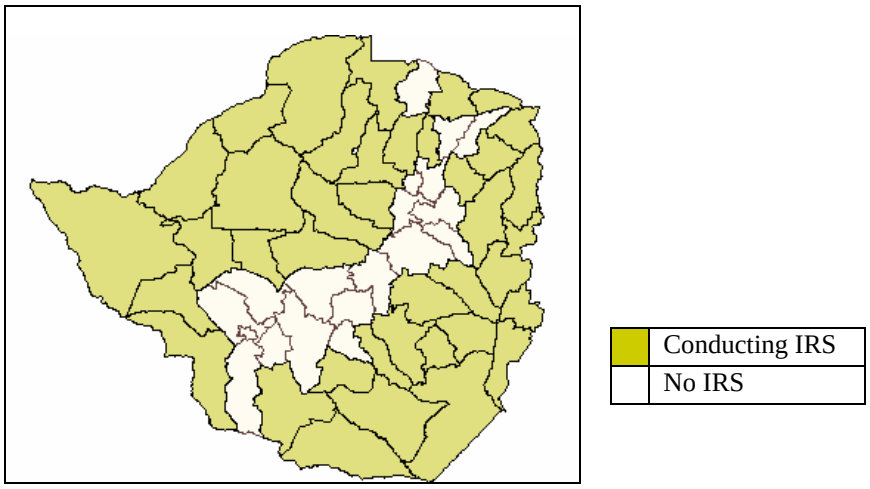
Figure 29. Malaria distribution and endemicity in Zimbabwe



3.17.2. Implementation and management of the IRS program

The practice of IRS for malaria control in Zimbabwe was initiated in 1947 and a large scale spraying program was launched in 1949 (Alves & Blair 1953, 1955 in Mabaso et al., 2004) using DDT. Indoor residual spraying continued expanding as a strategy of “barrier spraying” to prevent epidemics and the spread of the disease to the malaria free highveld parts of the country. Application of this strategy continued until 1970 when it was interrupted due to the war of liberation. Spraying was re-initiated in 1981 covering all malarious areas (blanket coverage approach). In the 1990s the blanket coverage strategy was replaced by selective spraying targeting high burden and high epidemic prone areas. However, over the past few years, geographical size and population coverage of the IRS program has been fluctuating due to inconsistent supply of resources. In 2003 spraying was conducted only in a few localities as a result of inadequate financial resources to secure insecticides. Nevertheless, coverage increased in the past 2 years due to support from the GFATM. In the 2005-2006 malaria season, 44 districts in the 8 provinces of Zimbabwe (Fig 30) were sprayed and 40% of the 5 500 000 at risk population was protected (Unpublished documents of Ministry of Health, Zimbabwe).

Figure 30. Districts in Zimbabwe conducting IRS, 2006



Policy/strategy and population coverage in 2006-2007 malaria season

Policy/ strategy	No. structures targeted to be sprayed	No. structures sprayed	Ave. operational coverage	Population protected	Trend of pop. coverage
-Routine IRS to control perennial & seasonal transmission -In response to epidemics if it is detected within a period of 2 weeks -Primarily in rural areas	1 839 727	1 271 474	82%	2 178 658 (39.6% of at risk population)	-Population coverage is expected to increase due to availability of resources & program expansion

Management and technical capacity

Basic documents	Planning	Spraying	Supervision	Funding
-IRS strategic plan available -National IRS guideline available	-IRS planed by national, province & district staff	-Spraying carried out by trained spray operators supervised by district health staff	-Supervisory check list available -Supervision done monthly by provincial & district supervisors	-MOH -Local authorities -GFATM -Partners

Monitoring and evaluation

Quality assessment with contact bioassay	Test on vector susceptibility to insecticides	IRS impact evaluation	
		Entomological indicators	Malaria burden
-WHO standard protocol available -WHO standard test kits available but not adequate -56 staff trained -Done once in a year	-No WHO standard protocol & test kits within the program (only in research institutes) -There are 8 sentinel sites -56 trained staff available -Tests done randomly	-Impact of IRS on the vector population density and sporozoite positivity rate not assessed	-Impact of IRS on malaria burden not evaluated

Maintenance and storage of spraying equipment

Storage capacity	Sprayers maintenance capacity
-Appropriate storage available (districts) -Storage checklist available -Districts store keepers responsible for storage of sprayers	-No checklist for cleaning, proper handling and basic maintenance of sprayers -No functional sprayer maintenance workshop, usually done at the field[15] -450 supervisors trained in sprayer maintenance, spray operators trained in very basic maintenance while trained in spraying

Pesticide management

Regulatory legislatives	Transport & storage	Handling, application & use	Waste management
-Insecticides used for IRS registered -Importation of insecticides controlled -Quality of insecticides checked -Insecticides for IRS given duty free certificates which exempts them from taxation	-No checklist on safe transportation & storage of insecticides -Appropriate storage available	-Checklist on proper handling of insecticides available -Protective gear for safe handling of insecticides used all times -Spray operators educated on occupational safety & health -Monitoring/inspection of sprayers is done by supervisors and team leaders on daily basis during spraying -Public education on safety awareness is done prior to the spraying and immediately after spraying of the respective households	-No checklist on proper disposal of pesticide containers, spray washes & other contaminated materials -But proper & safe disposal of the above is practiced as waste disposal of DDT is conducted in line with the Stockholm Convention

Insecticide application in 2006-2007 malaria season

Type	Amount of formulation used (kg)*	Active ingredient	Formulation
-DDT -Lambdacyhalothrin	-16 000 -18 000	-75% -10%	-WP -WP

* (There is a discrepancy between the reported sprayed number of structures and the amount of insecticide used. One would expect to spray 1 680 000 structures with this amount of insecticide not only 1 271 474)

3.17.3. Perspectives

Indoor residual spraying remains the mainstay of malaria control in Zimbabwe. The country has a history of managing quality and effective IRS, but in recent years resource constraints and scarcity of technical capacity has been a challenges to the IRS program. This has impacted on the quality and extent of the intervention. However, to date IRS management is improving and coverage is increasing as more resources are made available. A strategic plan to eliminate malaria in the southern province of the country was developed in 2006. This is linked to the malaria elimination plan in South Africa and Swaziland, which includes cross border collaboration in order to curtail the chance of reintroduction of the disease. More effort should be put in place to monitor impact of the intervention on the vector and malaria burden in the target areas.

[15] Resource is being mobilized to establish a central workshop

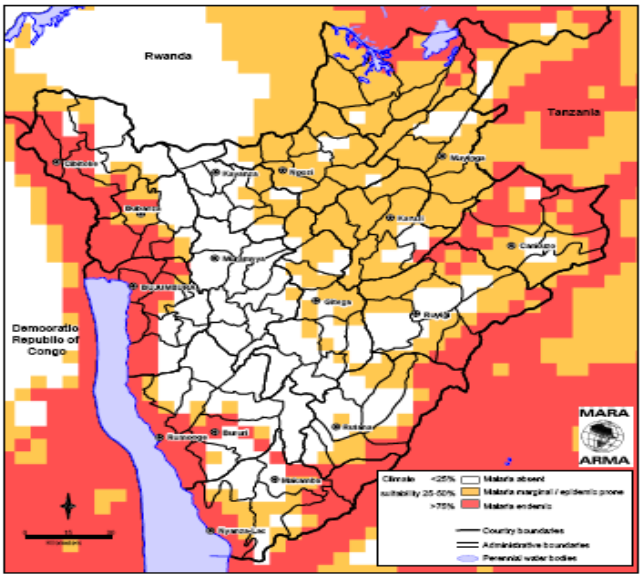
Countries conducting pilot IRS[16]

3.18. BURUNDI

3.18.1. Brief malaria epidemiology

Burundi has an estimated population of 7 000 000 of which about 6 600 000 are at risk of malaria infection. Malaria in Burundi is both endemic and epidemic (Fig 31) but most areas experience endemic malaria with perennial transmission. Only 6% of the population live under negligible risk, 25% are in areas at risk of epidemics and 69% reside in endemic malaria transmission areas (http://www.afro.who.int/malaria/country-profile/burundi.pdf, accessed on 6 Feb 2007). During the last decade Burundi has been stricken by a number of severe epidemics in seasonal malaria transmission areas. *Anopheles arabiensis*, *An gambiae s.s.* and *An. funestus* are important vectors. Vector susceptibility surveys conducted in 2005-2006 show that deltamethrin and DDT are effective against *An. funestus* and *An. gambiae* s.l. (98 to 100% mortality rate) while efficacy of permethrin is lower (87% mortality rate) (Unpublished report, NMCP of Burundi).

Figure 31. Malaria distribution and endemicty in Burundi



3.18.2. Implementation and management of the IRS program

Burundi is one of the countries where IRS pilot projects were conducted in the 1940s - 1960s. However, similar to many other countries in Africa, the pilot was not followed by large scale implementation other than being launched quite a few times in response to epidemics. In 2006, the country carried out a trial spraying in Ngozi province, using a pyrethroid insecticide, with a view to expanding depending on the experience and outcomes of the pilot. The pilot sprayed 13 169 structures and protected about 650 000 people.

3.18.3. Perspectives

No detailed information on the implementation of the pilot or any other IRS related issues has been accessed. However, in view of the endophelic nature of the two major vectors, *An. gambiae* and *An. funstus* in Burundi, IRS would have a significant impact on malaria transmission as long as availability of resources and technical capacity make its effective implementation feasible.

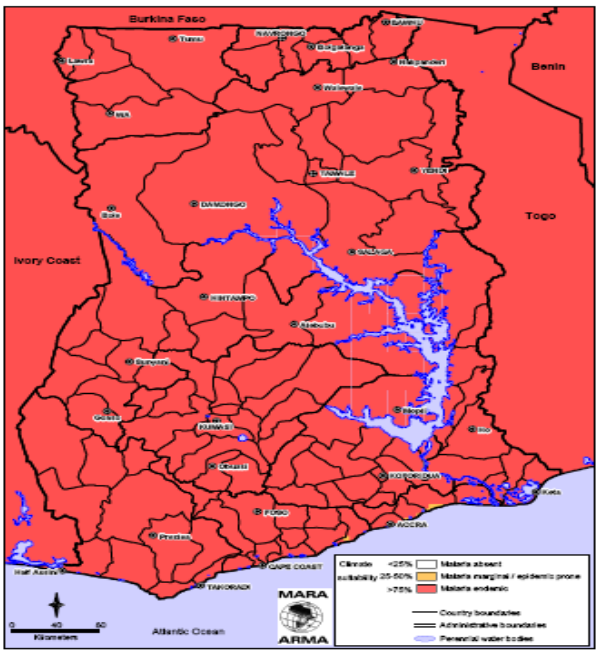
[16] Information on the IRS pilots in Nigeria and Senegal not yet reported.

3.19. GHANA

3.19.1. Brief malaria epidemiology

Estimated population of Ghana is 21 500 000 and the whole population is at risk of malaria infection (Fig. 32). Malaria is endemic throughout the country and transmission is perennial in most places. In the tropical forest areas transmission is intense with very limited fluctuation. In the coastal areas transmission is perennial and intense but with a marked decline during the dry season. Transmission in the savanna areas is also intense but minimal in the dry season. *Anopheles gambiae s.s* transmits most of the malaria along the coast while *An. arabiensis* is the most important vector in the savannah areas. *Anopheles funestus* also plays an important role while *An. melas* is a secondary vector. *Anopheles gambiae* s.s. is resistant to dieldrin (Brooke BD et al., 2006), DDT, carbamates and pyrethroids (Coetzee et al., 2006) while *An. funestus* is resistant to DDT and carbamates (Coetzee et al., 2006).

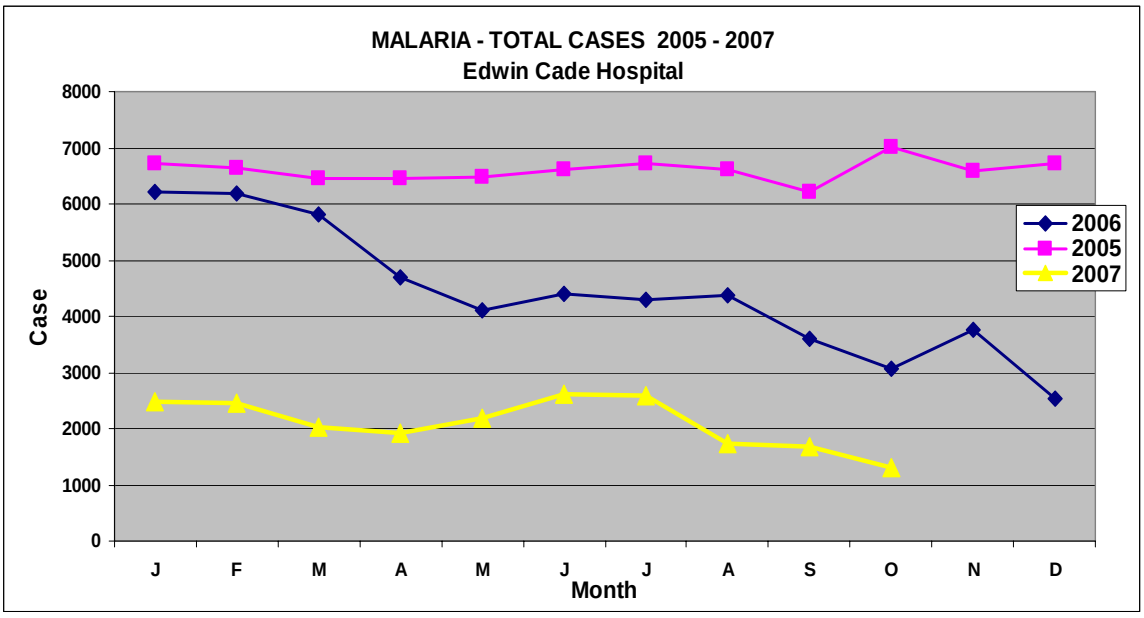
Figure 32. Malaria distribution and endemicity in Ghana



3.19.2. Implementation and management of the IRS program

Malaria control in Ghana focuses on case management and on promoting the use of ITNs. Recently, the malaria control program examined the feasibility and suitability of IRS as a component of its comprehensive effort to combat malaria. In mid 2006 AngloGold/Ashanti Mining Company, with the support of the NMCP, sprayed all structures where employees are residing as well as Obuasi town and the surrounding villages within the Obuasi municipality. 110 000 structures were treated with 18 560 kg of insecticide, using 116 spray operators, 60 pumps and 8 vehicles. A second round of spraying was conducted towards the end of the year, September 2006 in 130 000 structures. An estimated 230,000 inhabitants were protected through this pilot operation. The insecticide used was pirimiphos-methyl (WP) as organophosphates were the only class of insecticides to which full susceptibility of all vectors was shown (Coetzee et al., 2006). The same insecticide was used for targeted larviciding of some breeding sites. At present, after three spray rounds, a 75% reduction in malaria case incidence has been recorded in Obuasi (Fig. 33).

Figure 33. Malaria cases at Obuasi, Ghana, after implementation of IRS



3.19.3. Perspectives

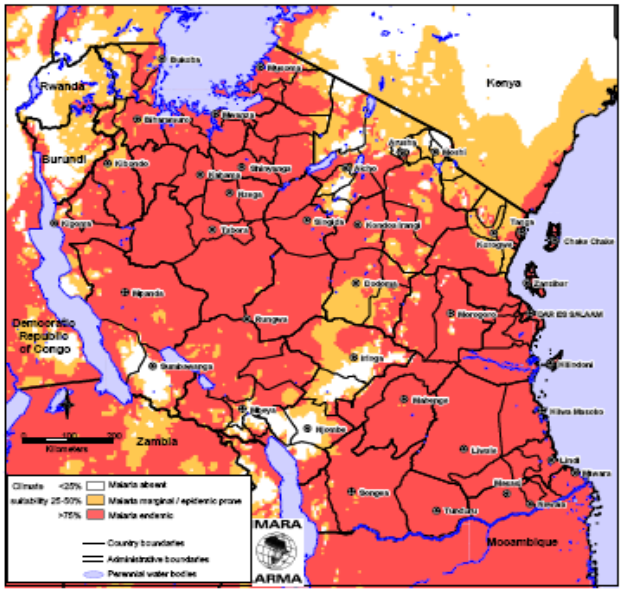
There is no information if the MOH of Ghana intends to expand IRS to more areas of the country concurrently with its nation wide ITN program. In any case, the resistance of the three major vectors to one or the other of the major groups of insecticide except organophosphates poses a problem to the application of IRS as a major component of the malaria control strategy.

3.20 TANZANIA MAINLAND

3.20.1. Brief malaria epidemiology

An estimated 33 00 000 people live in mainland Tanzania. Of these, 32 000 000 (94%) are at risk of malaria infection. Malaria in most areas is endemic with perennial transmission (Fig 34) and in some cases with seasonal peaks. There are 25 districts with areas that are prone to annual malaria epidemics. *Anopheles gambiae* s.s., *An arabiensis* and *An. funestus* are all important malaria vectors. *Anopheles merus* is known to be a secondary vector in the coastal areas. There is no information on the status of susceptibility of the vectors to insecticides at program level. However, research institutions particularly NIMR do carry out tests.

Figure 34. Malaria distribution and endemicity in Tanzania



3.20.2. Implementation and management of the IRS program

Application of pyrethrum against malaria vectors was practiced in the mainland Tanzania in the 1930s when small scale spraying activities were carried out using pyrethrum. At the beginning, spraying was done mostly in Dar es Salaam city. Later on, it was expanded to other urban areas notably to Tanga & Morogor. IRS was introduced in 1946 using DDT and continued until 1960. During this period there was the famous Pare-Taveta large scale IRS pilot project conducted around the border districts of Taveta in Kenya and Pare in Tanzania from 1954 – 1959. DDT and dieldrin were used in the project. After 1960, there has been no major project or program implementing IRS for malaria control in Tanzania until 1988. In 1988, a donor funded IRS project was launched in Dar es Salaam and Tanga as part of an integrated vector control approach where larviciding and environmental management were components of the vector control package. The project was ceased in 1996 as a result of change in policy in favor of ITNs. Since then no government or donor funded IRS had been implemented in mainland Tanzania.

However, in 2005-2006 small scale spraying has been carried out in Dar es Salaam city by the private sector. The insecticide used was lambdacyhalothrin, but no detailed information on this activity has been made available to the NMCP.

3.20.3. Perspectives

Although Tanzania is one of the pioneers in launching indoor spraying in the early days of the 20th century, the method has not been applied consistently to achieve a significant and sustained impact. There have been a number

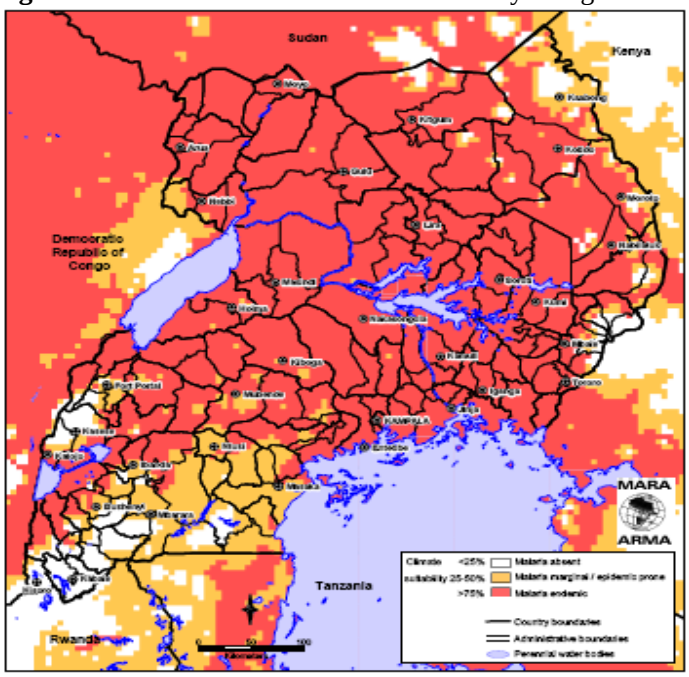
of short lived initiatives. At present, the country plans to re-introduce IRS to prevent and control malaria epidemics in 25 epidemic prone districts. The intervention is expected to complement the ITN program. Tanzania is intensively promoting the use of ITNs in almost all parts of the country particularly in urban centers using the voucher system for pregnant women and children under five years of age.

3.21. UGANDA

3.21.1. Brief malaria epidemiology

The estimated population of Uganda is 27 400 000, of which about 95% is at risk of malaria infection. Malaria transmission in Uganda varies from intense in most parts of the country, through medium in the south and north east, to low and very low mainly in the south (Fig 35). There are 15 epidemic prone districts. *Anopheles gambiae* s.l. and *An. funestus* are important vectors. Both groups are susceptible to the main insecticides for public health use (Unpublished documents of NMCP of Uganda). However, decreased susceptibility of *An. gambiae* s.s to permethrin (a opyrethroid insecticide) has been recorded earlier (Bagayoko M. et al 2005)

Figure 35. Malaria distribution and endemicity in Uganda



3.21.2. Implementation and management of the IRS program

IRS pilot projects were conducted in the 1940-1960s in urban areas particularly in Kampala where a dramatic reduction of disease transmission was documented. As in many other countries in the region, the pilot project did not expand or continue for a long time except for sporadic spraying activities in some epidemic prone areas, particularly from 1997 onwards. However, efforts to control malaria in Uganda have mainly been through case management and more recently through use of ITNs. The NMCP is considering reintroduction of IRS as a major intervention to control epidemics in unstable malaria areas and in all areas where internally displaced people (IDP) are settled. In 2006 a pilot project was initiated in Kabale district with the support of PMI. An outcome of the pilot project and other relevant information is summarized in the table below.

Policy/strategy and population coverage in 2006 malaria season

Policy/ strategy	No structures targeted to be sprayed	No structures sprayed	Ave. operational coverage	Pop. protected	Trend of population coverage
-Plan to conduct routine IRS to control epidemics -In all epidemic prone districts -In IDP sites	107 634	103 329	96%	488 502 (96% of target population)	-Expected to increase as the pilot trial give way to routine spraying

However, no information on the type of insecticide applied, if any insecticide resistance test has been conducted before spraying was launched and the impact of the pilot spraying on malaria burden has been made available.

3.21.3. Perspective

The program plans to expand and cover 9 more epidemic prone districts and other areas where IDPs are settled (including perennial transmission areas) by the year 2008. IRS would be the major vector control intervention with ITNs as a supplementary measure in these areas. A trial on feasibility of IRS under these circumstances has been conducted. The National Environment Management Authority has approved the re-introduction of DDT for IRS following an environmental impact assessment and a public hearing on the proposed re-introduction of the insecticide for malaria control. National technical capacity for undertaking IRS has been strengthened. Recently, a national team of 14 vector control officers from the Ministry of Health has been trained in planning, implementation and monitoring of national IRS activities. It is this team which will carry out the training of regional and district implementers of IRS including the local spray operators. Accordingly, the managerial capacity of the NMCP has been re-enforced by the appointment of an additional medical officer in the Monitoring and Evaluation unit of the program. A National Multi-Sectoral Committee that will monitor IRS issues has also been constituted but is yet to be inaugurated.

4. REFERENCES

1. Abate A, Hadis M, Taye A, Ameneshewa B, Medhin A, Tilahun D and Asfaw T. (2006). Susceptibility/Resistance Status of *Anopheles gambiae* sensu lato to DDT, Malthion, Permethrin and Deltamethrin in Sabure, Bahirdar and Awassa Zuria Areas, Ethiopia. *Survey Report of the NINH.*
2. Ameneshewa B and Service MW. (1996). The relationship between female body size and survival rate of the malaria vector *Anopheles arabiensis* in Ethiopia. *Med Vet Entomol*, 10: 170-172.
3. Bagayoko M, Ameneshewa B, Faye O, Govere J, Gebremariam M and Manga L. (2005). The status of malaria vector resistance to insecticides used for public health in the African Region. *Comm Dis Bull WHO Afr Region, Vol. 3, No. 1*.
4. Berzosa PJ, Cano J, Roche J, Rubio JM, Garcia L, Moyano E, Guerra A, Mateos JC, Petrarca C, Do Rosario V and Benito A. (2002). Malaria vectors in Bioko Island (Ecuatorial Guinea): PCR determination of the members of *Anopheles gambiae* Giles complex (Diptera: Culicidae) and pyrethroid knock down resistance (kdr) in *An. gambiae* sensu stricto. *J Vector Ecol*, 27: 102–106.
5. Bradley DJ. (1991). Morbidity and mortality at Pere-Taveta, Kenya and Tanzania, 1956-66: the effects of a period of malaria control. In: *Disease and Mortality in Sub-Sahara Africa.* Feach RG and Jamison DT, Oxford University Press. pp: 248-263.
6. Brooke BD, Kloke G, Hunt RH, Temu EA, Koekemoer LL, Taylor ME, Small G, Hemingway J and Coetzee M. (2001). Bioassay and biochemical analyses of insecticide resistance in southern African *Anopheles funestus* (Diptera: Culicidae). *Bull Entomol Res*, 91: 265-272.
7. Brook BD, Hunt RH, Matambo TS, Koekemoer LL, Van Wyk P and Coetzee M. (2006). Dieldrin resistance in the malaria vector *Anopheles gambiae* in Ghana.*Med Vet Entomol*, 20: 294-299.
8. Bruce-Chwatt LJ. (1984). Lessons learnt from applied field research activities in Africa during the malaria eradication era. *Bull World Health Org*, 62: 19-29.
9. Cano J, Berzosa PJ, Roche J, Rubio JM, Moyano E, Guerra-Neira A, Brochero H, Mico M, Edú M and Benito A. (2004). Malaria vectors in Bioko Island (Equatorial Guinea): Estimation of vector dynamics and transmission intensities. *J Med Entomol*, 41: 158-162.
10. Cano J, Descalzo MA, Moreno M, Chen Z, Nzambo S, Bobuakasi L, Jesús N, Buatiche JN, Ondo M, Micha F and Benito A. (2002). Spatial variability in the density, distribution and vectorial capacity of anopheline species in a high transmission village (Equatorial Guinea). (http://www.malariajournal.com/contents/5/1/21/abstract. Accessed on 14 Feb 2007).
11. Coetzee M, Van Wyk P, Booman M, Koekemoer LL and Hunt RH. (2006). Insecticide resistance in malaria vector mosquitoes in a gold mining town in Ghana and implications for malaria control. *Bull Soc Pathol Exot*, 99: 400-403.
12. Covell G, Mulligan HW and Afridi MK. (1938). An attempt to control malaria by the destruction of adult mosquitoes with insecticidal sprays. *J Mal Inst India*, 1: 105-113.
13. Cuamba N., Choi KS and Townson H. (2006). Malaria vectors in Angola: distribution of species and molecular forms of the *Anopheles gambiae* complex, their pyrethroid insecticide knockdown resistance (kdr) status and *Plasmodium falciparum* sporozoite rates. *Malaria Journal*, 5: 2.
14. De Meillon B. (1936). The control of malaria in South Africa by measures directed against the adult mosquitoes in habitations. *Quarterly Bull Health Org L o N*, 5: 134-137.
15. De Zuleta J, Kafuko GW, McCrae AWR et al. (1964). A malaria eradication experiment in the highlands of Kigazi, Uganda. *E Afr Med J*, 41: 102-120.
16. Garrett-Jones C. (1964). Prognosis for interruption of malaria transmission through assessment of the mosquito's vectorial capacity. *Nature*, 204: 1173-1174.
17. Garrett-Jones C and Grab B. (1964). Impact on the malaria mosquito vectorial capacity from data on the proportion of parous females. *Bull World Health Org*, 31: 71-86.
18. Giglioli G. (1972). Changes in the pattern of mortality following the eradication of hyperendemic malaria from a high susceptible community. *Bull World Health Org*, 46: 181-202.
19. Global Health Council. (2003). Reducing Malaria Burden: evidence of Effectiveness for Decision Makers. Technical Report December 2003.
20. Gramiccia G and Hempel J. (1972). Mortality and morbidity from malaria in countries where malaria erardication is not making satisfactory progress. *J Trop Med Hyg*, 75: 187-192.

21. Guillet P and Govere J. (2005). Les résistance des vecteurs du paludisme aux insecticides : propositions pour la mise en place d'un suivi et d'une politique de gestion à Madagascar. Rapport de Mission, 7-19/11/2005, Vector Biology and Control Unit, WHO Regional Office for Africa.
22. Hargreaves K, Koekemoer LL, Brooke BD, Hunt RH, Mtembu DJ and Coetzee M. (2000). *Anopheles funestus* is resistant to pyrethroids in South Africa. *Med Vet Entomol*, 14: 181-189.
23. Hargreaves K, Hunt RH, Brooke B, Mthembu J, Weeto MM, Awolola TS and Coetzee M. (2003). *Anopheles arabiensis* and *An. quadriannulatus* resistance to DDT in South Africa. *Med Vet Entomol*, 17: 417-422.
24. Jacobsen CJL, Gamage-Mendis A, Bule E, Dgedge M, Thompson R, Cuamba N, Barreto J, Begtrup K, Sinden R E and Høgh B. (2000). *An. arabiensis* and *An. funestus* are equally important vectors of malaria in Matola coastal suburb of Maputo, southern Mozambique. *Med Vet Entomol*, 14: 171-180.
25. Kouznetsov RL. (1977). Malaria control by application of indoor spraying of residual insecticides in tropical Africa and its impact on community health. *Trop Doctor*, 7: 81-91.
26. Mabaso MLH, Sharp B and Lengeler C. (2004). Historical review of malaria control in southern Africa with emphasis on the use of indoor residual house-spraying. *Trop Med International Health*, 9: 846-856.
27. Masendu HT, Hunt RH, Govere J, Brooke BD, Awolola TS and Coetzee M. (2004). The sympatric occurrence of two molecular forms of the malaria vector *Anopheles gambiae* Giles *sensu stricto* in Kanyemba, in the Zambezi Valley, Zimbabwe. *Trans R Soc Trop Med Hyg*, 98: 393-396.
28. Masendu HT, Hunt RH, Koekemoer LL, Brooke BD, Govere J. and Coetzee M. (2005). Spatial and temporal distributions and insecticide susceptibility of malaria vectors in Zimbabwe. *Afr Entomol*, 13: 25-34.
29. Medical Care International. (2006). Quarterly progress report, Number 12 , Equatorial Guinea Malaria Control Initiative, Bioko Island Malaria Control Project, July – September 2006.
30. Meek S, Hill J and Webster J. (2001). The Evidence Base for Interventions to Reduce Malaria Mortality in Low and Middle-Income Countries. CMH Working Paper Series, Paper No. WR5: 6.
31. Molineaux L and Gramiccia G.(1980). The Garki project: Research on the epidemiology and control of malaria in the Sudan Savana of West Africa. Geneve, *World Health Organization*.
32. Mouchet J, Laventure S, Blanchy S, Fioramonti R, Rakotonjanabelo A, Rabarison P, et al. (1997). La reconquete des hauts plateaux de Madagascar par la malaria. *Bull Soc Pathol Exot*, 90: 62-168.
33. Najera JA. (2000). Epidemiology in the strategy of malaria control. *Parassitologia*, 42: 9–24.
34. Najera JA. (2001). Malaria control: achievements, problems and strategies. *Parassitologia*, 43: 1–89.
35. Park Ross G. (1936). Insecticide as a major measure in the control of malaria, being an account of the methods and organizations put into force in Natal and Zululand in the past six years. *Quarterly Bull Health Org L o N*, 5, 114-133.
36. Payne D, et al. (1976). Impact of control measures on malaria transmission and general mortality. *Bull World Health Org*, 54: 369-377.
37. Pringle G. (1969). Experimental malaria control and demography in a rural East African community: a retrospective. *Trans R Soc Trop Med Hyg*, 63: 2-18.
38. Reimer LJ, Tripet F, Slotman M, Spielman A, Fondjo E and Lanzaro GC. (2005). An unusual distribution of the kdr gene among populations of *Anopheles gambiae* on the island of Bioko, Equatorial Guinea. *Insect Mol Biol*, 14: 683-688.
39. Sharma GK. (1987). A critical review of the impact of insecticidal spraying under National Malaria Eradication Program (NMEP) on the malaria situation in India. *J Comm Dis*, 19: 187-290.
40. Sharp B and Le Sueur D. (1996). Malaria in South Africa: The past, the present and selected implications for the future. *S Afr Med J*, 86: 978-979.
41. Sharma VP. (1996). Re-emergence of malaria in India. *Indian J Med Res*, 103: 26-45.
42. Sharp BL, Kleinschmidt I, Streat E, Maharaj R, Barnes KI, Durrheim DN, Ridel FC, Morris N, Seocharan I, Kunene S, La Grange JP, Mthembu JD, Maartens F, Martin CL and Barreto A. (2007). Seven years of regional malaria control collaboration – Mozambique, South Africa, and Swaziland. *Am J Trop Med Hyg*, 76: 42-47.
43. Teklehaimanot A. (2003). Report on malaria mission to Sao Tome & Principe. October 2003. http://www.earthinstitute.columbia.edu/cgsd/STP/documents/ReportMalariaMssionOct03.pdf. Accessed on 13 Feb 2007.

44. Utzinger J, Tozan Y, Doomani F and Singer BH. (2002). The economic payoffs of integrated malaria control in the Zambian copperbelt between 1930 and 1950. *Trop Med Intnl Hlth*, 7: 657-677.
45. World Health Organization. (2006). Indoor Residual Spraying: Use of Indoor Residual Spraying in Malaria Control and Elimination. Global Malaria Control Program. WHO/HTM/MAL.2006.1112.
46. World Health Organization Regional Office for Africa. (2006). Consultative meeting on the use of Dichloro-Diphenyl-Trichloroethane (DDT) for indoor residual spraying (IRS) in the African Region. Brazzaville, Congo, 20 – 22 June 2006.
47. Zahar AR. (1985). The vector bionomics in the epidemiology and control of malaria. Part I. The WHO African Region and the Southern WHO Eastern Mediterranean Region. World Health Organization, Geneva (VBC 84.6, 85.1-3).

5. ANNEX

Annex 1. Summary of recommendations and endorsements of the meeting on the use of Dichloro-diphenyl-trichloroethane (DDT) for indoor residual spraying (IRS) in the Africa Region, Brazzaville, Congo, 20 - 22 June 2006

The meeting:

1. *Endorses,* as still valid, the existing WHO guidelines and recommendations for the use of DDT for indoor residual spraying.
2. *Asserts* that indoor residual spraying (IRS) is effective in both stable and unstable malaria transmission areas.
3. *Recognizes* that to be effective, IRS requires specific technical and operational capacities, as well as ongoing financial commitment by Governments.
4. *Notes* that the use of DDT for IRS remains a cost-effective intervention for most parts of Africa, in areas where vectors are susceptible, and it is expected that its use will continue for the foreseeable future.
5. *Notes* that because of the diminishing arsenal of available cost-effective insecticides for malaria vector control, as well as the challenges of vector resistance, it is imperative that the currently pesticides including DDT be seen as resources for both current and future generations. Therefore, countries should ensure effective management and judicious use of pesticides, and establish resistance management practices to prevent or slow down development of resistance. Opportunities for these are presented by inter-country and sub-regional mechanisms for vector resistance monitoring and management, such as the African Network for Vector Resistance (ANVR).
6. *Acknowledges* the important role of ongoing toxicological evaluation under the auspices of WHO in order to ensure the timely review of new research findings concerning health effects of all insecticides approved for malaria control, timely update of existing recommendations, and prompt dissemination of these updates, to inform country decision-making.
7. *Recognizes* that appropriate policies, effective regulation and enforcement, are important for all public health insecticides particularly DDT. Intersectoral collaboration is required in this regard.
8. *Recognizes* the existence of heterogeneity among countries in economic conditions, infrastructure, disease ecology and epidemiology, and that consequently, a single intervention will not fully address all situations, rather different vector control interventions will have different roles according to the epidemiological setting.
9. *Acknowledges* that IRS should be deployed within the context of an integrated vector management strategy. The synergetic combination of locally appropriate interventions would maximize program impact on local disease burden.
10. *Calls on countries to*:
    a. Ensure careful decision making and flexibility in the selection of interventions and the allocation of resources to various options, with a long term view on feasibility and sustainability of full coverage
    b. Build/strengthen relevant capacities to plan, implement, monitor and evaluate appropriate malaria vector control interventions, including IRS with DDT.
    c. Establish systems for prospective monitoring of potential adverse effects of insecticides, particularly DDT.
    d. Document and disseminate lessons learnt in the use of DDT.
    e. Follow existing WHO guidelines and recommendations on the use of DDT for IRS.
11. *Calls on WHO and partners to*:
    a. Provide support in achieving the goals set out under paragraph 10 above, recognizing that the current interest by countries to take full advantage of IRS poses serious challenges for capacity strengthening.
    b. Designate one or more WHO collaborating centers to support country evaluation of the effects of the use of DDT.