New evidence for conquering malaria:

Operations, Costs and Cost-Effectiveness:

Five Insecticide-Treated Net Programmes

(Eritrea, Malawi, Tanzania, Togo, Senegal)

Two Indoor Residual Spraying Programmes

(KwaZulu-Natal, Mozambique)

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Malaria deaths and resulting Disability–adjusted Life Years (DALYs, 1000s) lost in 2002

	Population	Malaria deaths	DALYs from malaria deaths (%)	DALYs from malaria / total (%)
World	6,122,210	1124	42,280	2.9
Africa	655,476	963	36,012 (85.2)	10.1
Americas	837,967	1	108 (0.2)	0.07
East Med.	493,091	55	2,050 (4.8)	1.5
Europe	874,178	<1	20 (0.04)	0.01
SE Asia	1,559,810	95	3,680 (8.7)	0.9
West Pacific	1,701,689	10	409 (1.0)	0.2

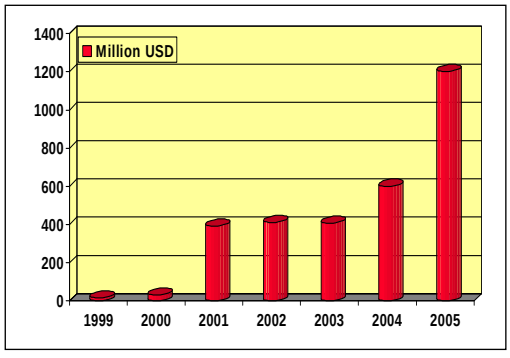
Adapted from WHO, World Health Report, 2002

Malaria-Related Mortality and Morbidity in Africa, 2000*

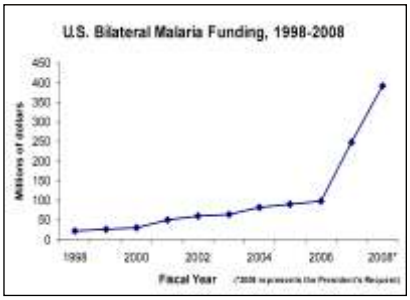
Condition	Total	By age in years (%)		
		0-4	5-14	≥ 15
Malaria-specific mortality	1,124,000	65	19	16
Maternal mortality (anemia)	5,300	---	---	100
Infant mortality (pregnancy-related)	71,000 – 190,000	100	---	---
Fatal adverse drug events	2,300	?	?	?
Fatal HIV from blood transfusion	5,300 – 8,500	100		---
Epilepsy-related mortality	Unknown	?	?	?
Anemia, undernutrition, and HIV mortality	Unknown	?	?	?
Morbidity attacks (1000s)	213,549 [134,322 – 324,.617]	51	35	14
Morbid days (1000s)	803,699 [494,416 – 1,.298,872]	69	21	10
Neuro-cognitive sequelae cerebral malaria				
Hemiparesis	360 - 400	100		?
Quadriparesis	770 - 860	100		?
Hearing impairment	650 - 730	100		?
Visual impairment	300 - 330	100		?
Behavioral difficulties	1,540 – 1,720	100		?
Language deficits	7,000 – 7,800	100		?
Epilepsy	2,700 – 3,000	100		?
Effect of malaria on cognition	Unknown	?	?	?

A favourable environment

60 x increase in global malaria control resources since 1999



Source: Updated from Waddington *et al*. (2005)



Source: Daulaire 2007

How to spend wisely these new resources ?

Aims of the review

To systematically review and compare the cost, cost-effectiveness, and main operational features of large-scale indoor residual spraying (IRS) and insecticide-treated nets (ITNs) for malaria control in sub-Saharan Africa.

IRS: KwaZulu-Natal, Southern Mozambique (LSDI)

ITNs: Eritrea, Malawi, Tanzania, Togo, Senegal

Methods of the review (1) – General principles

- **Costing followed standard guidelines (Creese & Parker 1994; Stevens *et al*. 2005; Kolaczinski *et al*. 2006).**
- **Only national or at least large-scale programmes.**
- **Provider perspective, with exception of user contributions to purchase of nets and insecticide kits.**
- **Time frame varied according to availability of data (if possible at least 3 years, including startup costs).**
- **Costs were collected retrospectively from financial and operational records; in addition, costs and activity information were collected through stakeholder interviews and direct observation, as needed.**
- **Where possible, the ingredients approach was used (unit activities were first determined and then a unit cost was determined).**

Methods of the review (2) - Costing

- Resource use was valued at all levels: central (within the MOH and the NMCP), at the district level, and peripherally.
- Costs have been divided into *capital* and *recurrent* costs; capital costs discounted at 3%.
- Both financial and economic analyses were conducted.
- Costs collected in local currencies were converted to USD based on official yearly average exchange rates; yearly costs were then adjusted to 2005 USD prices using the US GDP deflator produced by the US Bureau for Economic Analysis.
- In joint programmes, the likely share of vector control activities has been estimated

Methods of the review (3) – Output measures

- Two main output measures were used: (1) *number of nets delivered* and (2) *number of re-treatments performed*. The two were used to calculate a third combined output measure: *treated net years (TNY)*, assuming that either a re-treatment or a new ITN provides 1 year of full protection.
- When long-lasting insecticidal nets (LLIN) were used, they provided 3 TNY (Permanet type). This was extended to five years in the sensitivity analysis (Olyset type).
- Half of the nets delivered were assumed to be used by children; only one child was assumed to sleep under each of these nets.

Methods of the review (4) – Health benefits

Deaths averted

- **Mortality impact for ITNs taken from the Cochrane review: 5.5 deaths averted per 1000 person-years of protection in children under five years (U5s).**
- **For lack of better data, we assumed the same effect for IRS; there is much historical evidence of impact of IRS but no reliable quantification of this effect. Currently ongoing Cochrane review on IRS (Tanser, Pluess, Lengeler & Sharp).**
- **No quantification of protective effect in older individuals (especially relevant in areas with high HIV levels).**
- **No quantification of protection in pregnant women (although positive effects on newborns covered in U5s mortality).**
- **No effect of untreated nets – instead we calculated the effect of LLIN in the sensitivity analysis.**

Methods of the review (5) – Health benefits

Disability-adjusted life-years (DALYS)

- **Only included effect of mortality because difficult to include other forms of disabilities across seven settings.**
- **We used the standard WHO lifetable approach (Global Burden of Disease Project) and treated all deaths as infant deaths resulting in 33 lost DALYs; using country-specific lifetables would have introduced large differences between countries because of different life expectancies.**
- **For both outcomes we calculated CE ratios for (1) cost per net distributed and (2) cost per TNYs.**

Many of our methodological choices were guided by the imperative of *comparability*. They are conservative and unlikely to bias comparisons as long as country-specific age profiles of malaria morbidity and mortality are similar.

Comparing IRS with ITNs – is one better?

	PE IRS	PE ITN	Reference
Tanzania 12 villages Randomized	64%	55%	**Curtis *et al.* 1998**
South Africa 14 blocks Randomized	PE ITNs vs IRS: 33%		**Mnzava *et al.* 2001**
Kenya Non-random.	75%	63%	**Guyatt *et al.* 2002**
India 126 villages Randomized	30%	54%	**Misra *et al.* 1999**
Pakistan P.v. Non-random. P.f.	44% 49%	42% 61%	**Rowland *et al.* 1999**

PE= protective efficacy = (1-RR) x 100 **Lengeler and Sharp 2003**

It seems not… the results are very similar

IRS programmes under review:

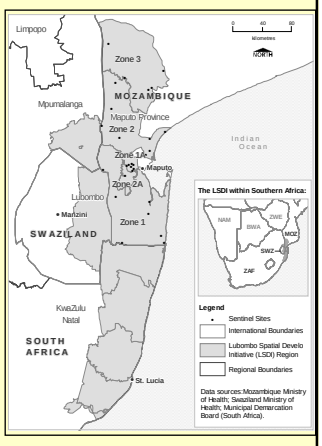
IRS programmes are the "model" vertical programmes… but they can be well integrated into the health system!

KwaZulu Natal:

- **Funded by the SA Dept. of health since 1932**
- **Seasonally hired spraymen (200) and supervisors (25) with 25 vehicles.**
- **Currently using DDT (traditional houses) and pyrethroids (Western-type structures)**

Southern Mozambique LSDI:

- **Funded by a consortium including GFATM**
- **Seasonally hired community-resident spraymen (80) and supervisors (2) with 2 vehicles.**
- **Currently using DDT (traditional houses) and pyrethroids (Western-type structures)**



Public sector

Commercial / mixed

ITNs: Current main implementation models

1. Free distribution of ITNs through health facilities and community groups (Eritrea).
2. Free distribution of ITNs in the frame of vaccination campaigns (Ghana, Togo, Zambia, Niger, Mozambique, Kenya, Rwanda).

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3. A comprehensive market approach (NETMARK project in Senegal, Mali, Ghana Nigeria, Mozambique, Uganda, Zambia, Ethiopia) – with and without subsidies.
4. Social marketing (Malawi, Kenya) – with subsidized ANC sales, with and without product distribution.
5. Integrated (NATNETS Tanzania): commercial sector distribution, social marketing with no product distribution and vouchers for pregnant women and infants at measles vaccination

Key characteristics of programmes

	Population covered (millions)	Period	Total # of nets	Total # re-treatments	Total economic cost (mio USD)
Eritrea	2.9	2001-05	900,000	2,000,000	4.4
Malawi	12.2	1999-05	4,700,000	500,000	15.7
Tanzania	35.7	2002-05	6,400,000	7,800,000	30.5
Togo (Mueller *et al.*)	5.3	2004	900,000	0	6.5
Senegal	10.0	2000-05	750,000	1,000,000	6.2
KwaZulu-Natal	0.6 (7.3 in past)	1997-99	300,000 structures		2.2
Mozambique	0.8	1999-01	150,000 structures		1.0

Average annual economic cost for ITN and IRS programmes. Conventional ITNs (2005 USD).

ITN program	Average cost per ITN distributed	Average cost per TNY	Cost per death averted	Cost per DALY averted
Eritrea	4.74	1.43	1,722	52
Malawi	3.36	3.04	1,222	37
Tanzania	4.80	2.17	1,745	53
Senegal	8.35	3.60	3,037	92
Togo (Mueller *et al.*)	3.23	3.23	1,174	36

IRS program	Cost per person protected (whole population)	Cost per under-five child protected	Cost per death averted	Cost per DALY averted
KwaZulu-Natal	3.27	23.96	4,357	132
Mozambique	3.90	21.63	3,933	119

Average annual economic costs for ITN and IRS programmes. LLIN with 3 years duration (2005 USD)

ITN program	Average cost per LLIN distributed	Average cost per TNY	Cost per death averted	Cost per DALY averted
Eritrea	7.64	1.48	539	16
Malawi	5.18	2.19	798	24
Tanzania	6.04	1.83	664	20
Senegal	7.89	3.60	1,311	40
Togo (Mueller *et al.*)	3.47	2.37	773	23

IRS program	Cost p. person protected (whole population)	Cost per under-five child protected	Cost per death averted	Cost per DALY averted
KwaZulu-Natal	3.27	23.96	4,357	132
Mozambique	3.90	21.63	3,933	119

Coverage rates of high-risk groups in study sites (latest figures available – %)

	Household ownership		Children under five slept under net last night		Pregnant woman slept under net last night	
	Any net	ITN	Any net	ITN	Any net	ITN
Eritrea 2004	79	73	na	48	na	50
Malawi 2004	43	34	38	36	34	31
Tanzania 2006	57	29	41	28	34	18
Togo 2004	na	60	na	54	na	45
Senegal 2005	38	20	14	7	14	9

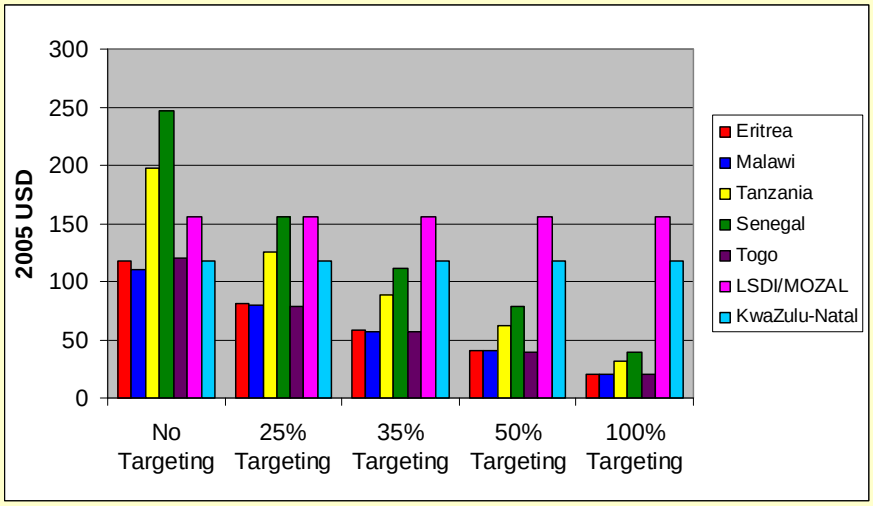
Coverage in both IRS areas above 80% for risk groups

Targeting of under-five children in the five ITN programs

	Eritrea	Malawi	Tanzania	Senegal	Togo
Percentage of population aged 0–4 years	17.2%	18.2%	15.8%	15.8%	16.5%
Targeting ratio as measured from cross-sectional surveys	31.8%	19.7%	24.7%	28.1%	20.2%
Programme targeting effort	***	**	**	*	***

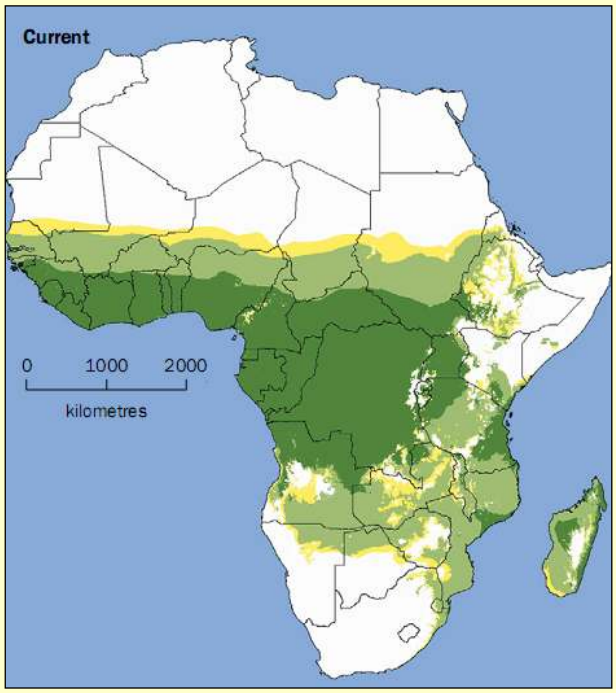
$$\text{Targeting Ratio} = \frac{n_{children} \cdot \text{child net usage}}{n_{total} \cdot \text{total net usage}}$$

Cost per DALY averted at different targeting levels for ITNs - using full economic cost at scale. Baseline results for IRS are shown for comparative purposes

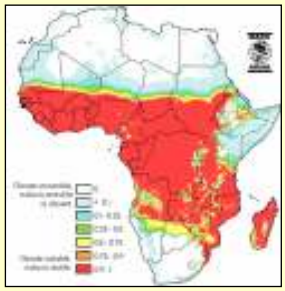


Epidemiological determinants

- **Seasonality is a major factor influencing the CE of IRS because of the need for increasing numbers of spray rounds with increasing length of the transmission season.**
- **Consensus among IRS implementers is that beyond two spray rounds per year IRS becomes very difficult to implement.**
- **Hence, in areas of year-round transmission, ITNs will have a significant feasibility and cost-effectiveness advantage.**
- **Especially true with the use of shorter-lived insecticides such as carbamates as opposed to insecticides with longer residual lifetimes.**
- **In areas of shorter and lower transmission and typically also in epidemic-prone zones, IRS may have significant advantages because IRS programmes protect the entire population and the burden of disease is likely to be distributed much more evenly across all age groups.**
- **IRS can be restricted to periods in which there is a clear risk of epidemic.**



Seasonality of transmission in sub-Saharan Africa
(Tanser *et al*. 2003)



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“Catch-up” versus “Keep-up” (RBM 2005)

- **Integrated vaccination-ITN campaigns such as in Togo have achieved high coverage rates within a short period of time. Hence, they fulfill the immediate needs for “catching-up” in ITN usage.**
- **However, on their own they are unable to maintain high net usage levels because (1) more women get pregnant and children are born, and (2) polyester LLIN have a finite uselife.**
- **Hence, there is also a strong need for “keep-up” programmes to maintain high net usage levels. Four of the ITN programs we reviewed tend to be more “keep-up” (Eritrea, Malawi, Senegal, Tanzania).**
- **These programs attempt this through the integration of ITN delivery into routine health services or other mechanisms such as vouchers linked to commercial sector distribution.**
- **Currently, there is a consensus that both “catch-up” and “keep-up” strategies are required in each country.**

Who bears the cost ?
LLINs with 3 years duration (2005 USD)

	Total cost	Cost to provider	% supported by donor	user	govt
Eritrea	**7.64**	**7.64**	**92**	**3**	**5**
Malawi	**5.18**	**4.12**	**80**	**19**	**1**
Tanzania	**6.04**	**2.18**	**47**	**52**	**1**
Senegal	**7.89**	**3.62**	**66**	**33**	**1**
Togo (Mueller et al.)	**3.47**	**3.47**	**99**	**0**	**1**
KwaZulu-N	**3.27 / 23.96**	**3.27 / 23.96**	**0**	**0**	**100**
Mozambique	**3.90 / 21.63**	**3.90 / 21.63**	**90**	**0**	**10 est.**

Level of involvement of public, private and NGO sectors in studied vector control programs

Programme	Public sector	Commercial sector	NGO sector
Eritrea	♦♦♦		♦
Malawi	♦♦	♦♦	♦♦
Tanzania	♦♦	♦♦♦	♦♦
Senegal	♦	♦♦♦	♦♦
Togo	♦♦		♦♦♦
KwaZulu-Natal	♦♦♦		
Mozambique	♦♦♦	♦	♦

Conclusions (1)

- For the first time, comparable large-scale programme data are available to provide a solid evidence base in the debate on the best approach to vector control in sub-Saharan Africa.
- Vector control is remarkably cost-effective in SSA: cost per DALY averted ranged between USD 16-40 for LLIN programmes and 119-132 for IRS programmes; cost per death averted ranged between USD 539-1311 for LLINs and USD 3,933-4,357 for IRS.
- For any ITN strategy, the use of LLIN rather than conventional nets should be promoted, regardless of the higher initial investment.
- The vaccination campaign approach fits best the RBM concept of "catch-up", while the 4 other models aim both for "catch-up" and "keep-up" over time; both strategies need to be combined.
- The longer the transmission season, the more LLINs are the better strategic option for vector control. IRS is likely to be better in epidemic-prone areas.

Conclusions (2)

- Some strategies are more cost-effective than others but each strategy also brings specific advantages, in the short-term and in the long-term; some of these approaches can be mixed, as in Tanzania.
- A commercial distribution strategy on its own can not produce high coverage levels and targeted subsidies must be incorporated.
- Targeting children under five years and pregnant women remains more cost-effective than protecting the whole population. The benefits of the latter approach could not be explored in the present study. For this reason, IRS is substantially more costly than any ITN strategy aiming at risk groups.

Most vector control programs are excellent public health investments and they should be made as soon as possible. This is a time of unprecedented opportunities for malaria control, and it is time to bring down substantially the unacceptable burden of disease.