

# **Preventing malaria: an evaluation of alternative methods using the cost-effectiveness technique**

Yanying Lou

Supervisor: Professor Geoff Harris

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## **Declaration**

I, Yanying Lou, declare that this dissertation

**Preventing malaria: an evaluation of alternative  
methods – using the cost-effectiveness technique**

is my own work and that all sources I have used or quoted have been indicated and acknowledged.

Durban, 2003

## Abstract

Malaria is the one of most important diseases in the world, especially in sub-Saharan Africa. This dissertation outlines the enormous burden of the disease in terms of social and economic costs in southern Africa.

This dissertation assessed the range and quality of the cost-effectiveness of malaria prevention in sub-Saharan Africa. Six studies published from 1999 to 2003 are reviewed, covering insecticide treated nets, residual spraying, chemoprophylaxis for infants and environmental management. For infants, ITNs cost from US\$ 2019 – \$2879 per death averted and cost \$ 111 per DALY; chemoprophylaxis cost \$ 4.1 per DALY and chemoprophylaxis plus iron cost \$ 5.0 per DALY. For children, ITNs cost \$ 1559 per death averted, \$ 57 per DALY and \$ 61 per sick child averted. For non-specific age group, ITNs cost \$ 29 per infection averted, and RHS \$ 9.

Generally all interventions assessed are cost effective use of resources. The chemoprophylaxis is the least expensive malaria prevention among cost effective malaria prevention interventions, followed by residual spraying one round a year, residual spraying two rounds a year, insecticide treated nets with net treatment only and insecticide treated nets with net provision and treatment.

There are operational, managerial and financial challenges faced these most cost-effective malaria interventions. Particularly, chemoprophylaxis is faced the tremendous drug resistance potential and is not being recommended to wide use; financial constraints and the potential delaying of children's immunity acquisition lowers the cost-effectiveness of insecticide treated nets; residual spraying is a relatively simpler, faster and cheaper method, but faces political and economic pressure of concerning environmental issues, especially the use of DDT.

The integrated approach of environmental management plus residual spraying could be the most cost-effective method of malaria prevention with least adverse environment effects. However, policy makers should apply their knowledge to local conditions. Further, comprehensive education programmes are needed to gain support and understanding from local communities. This would raise the cost-effectiveness of all interventions.

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## Abbreviations

CBA	cost-benefit analysis
CEA	cost-effectiveness analysis
CMA	cost-minimisation analysis
CUA	cost-utility analysis
DA	death averted
DALY	disability adjusted life year
DDT	dichlorophenyltrichloroethane
DLYG	discounted life year gain
EM	environmental management
EPI	Expanded Programme On Immunization
GDP	gross domestic production
GNP	gross national production
ITN	insecticide-treated net
KINET	Kilombero Valley Insecticide-Treated Net Project
NAMP	national anti-malaria programme
RBM	Roll Back Malaria
RHS	residual house spraying
SSA	sub-Saharan Africa
UNICEF	United Nations Children's Fund
WHO	World Health Organization

# CHAPTER 1 INTRODUCTION

## 1.1 Background

Malaria is a public health problem in more than 90 countries, inhabited by a total of some 2.4 billion people, representing about 40% of the world's population (WHO, 1998). Best estimates currently describe the annual global burden of malaria as 1.1 million deaths, 300-500 million cases, 44 million disability adjusted life years (DALYs) ([www.who.int/tdr/diseases/malaria/](http://www.who.int/tdr/diseases/malaria/)). It has been estimated that the economic burden is also extremely high, accounting for a reduction of 1.3 percentage points in the annual economic growth rate of malaria endemic countries and that the long term impact of this is a reduction of gross national production (GNP) by more than half (Sachs and Malaney, 2002).

Over 90% of the disease burden is in sub-Sahara Africa, and almost all deaths due to plasmodium falciparum (one of four types of human malaria), occur in Africa, south of the Sahara ([www.who.int/tdr/diseases/malaria/](http://www.who.int/tdr/diseases/malaria/)), where malaria also presents major obstacles to social and economic development. Malaria has been estimated to cost Africa more than US\$ 12 billion every year in lost GDP ([http://www.rbm.who.int/cmc\\_upload/0/000/016/370/RBMInfosheet\\_3.htm](http://www.rbm.who.int/cmc_upload/0/000/016/370/RBMInfosheet_3.htm)).

The malaria burden differs according to age and gender. Almost all deaths occur in African children under 5-years-old. Older Africans have reduced risk due to an ability to develop a degree of immunity to the disease as a result of continuous exposure. Outside Africa, where continuous exposure does not occur, the disease burden extends into adulthood. Pregnant women in Africa (especially primigravidae) are at high risk and are the major adult risk group in Africa. The malaria burden associated with pregnancy has an additional impact due to the effect on the health of the foetus ([www.who.int/tdr/diseases/malaria/](http://www.who.int/tdr/diseases/malaria/)).

Areas on the northern and southern fringes of the malaria-endemic belt of Africa, as well as highland areas in many countries, are at risk of epidemic malaria. Unlike the endemic disease, epidemic malaria affects people of all ages and can have high case-

fatality. Malaria also poses a risk to travellers and immigrants, with imported cases increasing in non-endemic areas ([www.who.int/tdr/diseases/malaria/](http://www.who.int/tdr/diseases/malaria/)).

Major trends over the last few decades point to a worsening situation making effective action essential. These major trends include an increase in epidemic malaria; upward trends in mortality over the last three decades, including in sub-Saharan Africa; an upward trend in drug-resistant *P. falciparum* malaria; the re-emerging of *P. vivax* malaria in areas from where it had been previously eradicated e.g. Caucasus and Central Asia; and an increase in imported malaria in the developed world ([www.who.int/tdr/diseases/malaria/](http://www.who.int/tdr/diseases/malaria/)).

Thirty years after the abandonment of the first 'global' campaign to eradicate malaria, the disease is again high on the international health agenda. In 1998, Roll Back Malaria (RBM) was founded as a global partnership by the World Health Organization (WHO), the United Nations Development Programme (UNDP), the United Nations Children's Fund (UNICEF) and the World Bank with the goal of halving the world's malaria burden by 2010. The RBM partnership includes national governments, civil society and non-governmental organizations, research institutions, professional associations, UN and development agencies, development banks, the private sector and the media ([http://mosquito.who.int/cgi-bin/rbm/dhome\\_rbm.jsp?ts=3238061358&service=rbm&com=gen&lang=en&type=intro&channelId=-8254&chLevel=2&p=rbminitiative](http://mosquito.who.int/cgi-bin/rbm/dhome_rbm.jsp?ts=3238061358&service=rbm&com=gen&lang=en&type=intro&channelId=-8254&chLevel=2&p=rbminitiative)).

RBM suggests a number of evidence-based, cost-effective interventions, which if brought to scale in malaria-endemic countries, could have a significant impact on both the morbidity and mortality of malaria. These suggestions include:

- ❖ Early diagnosis and prompt effective treatment of malaria
- ❖ Prevention of malaria through use of insecticide-treated materials and other vector control measures including residual indoor spraying, larviciding and environmental management
- ❖ Early detection and prevention of epidemics, and rapid response to epidemics, through monitoring, surveillance, preparedness, timely action.
- ❖ Development of new tools, strategies and methodologies, together with the improvement in delivery of existing tools through research and development

- ❖ Coordinated action through establishing partnerships that utilize an optimal mix of measures adapted to local situations  
([www.who.int/tdr/diseases/malaria](http://www.who.int/tdr/diseases/malaria)).

However, health policy-makers cannot decide on whether an intervention or programme is worth supporting unless they have information on not only its effectiveness but also its costs. Economic evaluation could make a substantial contribution to malaria control decision-making. Given that malaria imposes an economic burden on individuals and governments, disease reduction can therefore produce savings in resources. Since resources are scarce, putting money into one activity is always at the expense of not doing something else. Therefore, simply knowing that there is an intervention that works is not sufficient to decide to spend money on it. Policy-makers must compare the costs and effectiveness of the intervention, with the costs and effects of additional investment in other services.

The research on the costs of an intervention is as important as research on its effectiveness. Cost-effectiveness analysis could provide the information that is needed by health policy-makers for decision-making. Costs are divided by health effects to obtain a cost per unit of health effect, known as the cost-effectiveness ratio (Mills, [http://mim.nih.gov/english/achievements/mim\\_conference-05.pdf](http://mim.nih.gov/english/achievements/mim_conference-05.pdf)).

## **1.2 Overall Objective And Specific Aims**

This dissertation overall objective is to review cost-effectiveness analyses of malaria prevention published from 1999 up to the middle of 2003, in the African context. The specific aims are:

- ❖ To outline the extent of malaria in southern Africa, its social and economic costs, to list the alternative preventive measures and current malaria control strategy
- ❖ To explain cost-effectiveness analysis (CEA) as a method of deciding between alternative means of preventing malaria

- ❖ To review a large number of studies of preventive method to deal with malaria, using a CEA framework, in order to show what methods are most cost effective

Studies of cost-effectiveness analyses before 1999 have been reviewed by Goodman et al (1999a), so this dissertation focuses on subsequent studies. Early studies of the cost-effectiveness of malaria control were made by Barlow and Grobar (1986) and Mills (1987).

### **1.3 Overview**

- ❖ Chapter 2 will outline the extent of malaria in southern Africa, and its social and economic costs; list the alternative preventive means and describe current control strategy. It will then compare the malaria eradication programme with the current malaria control strategy.
- ❖ Chapter 3 will explain CEA as a method of deciding between alternative means of preventing malaria.
- ❖ In chapter 4, CEAs of malaria prevention published from 1999 up to middle 2003 in African context will be reviewed.
- ❖ In chapter 5, the comprehensive discussions on application complexity of both cost-effectiveness analyses on the subject and malaria prevention interventions will be presented.
- ❖ Chapter 6 will be the conclusion of the study.

## **CHAPTER 2 THE MALARIA PROBLEM IN SOUTHERN AFRICA**

### **2.1 Malaria And its Epidemiology**

Malaria affects the lives of almost all people living in the area of Africa defined by the southern fringes of the Sahara Desert in the north, and latitude of about 28 degree in the south. Most people at risk of the disease live in areas of relatively stable malaria transmission – infection is common and occurs with sufficient frequency that some level of immunity develops. A smaller proportion of people live in areas where risk of more seasonal and less predictable, because of either altitude or rainfall patterns. People living in the peripheral areas north or south of the main endemic area or bordering highland areas are vulnerable highly seasonal transmission and to malaria epidemics (WHO/UNICEF, 2003, p17).

In areas of stable malaria transmission, very young children and pregnant women are the population groups at highest risk for malaria morbidity and mortality. Most children experience their first malaria infections during the first year or two of life, when they have not yet acquired adequate clinical immunity – which makes these early years particularly dangerous. Ninety percent of all malaria deaths in Africa occur in young children. Older Africans have reduced risk due to an ability to develop a degree of immunity to the disease as a result of continuous exposure. Adult women in areas of stable transmission have a high level of immunity, but this is impaired especially in the first pregnancy, with the result that risk of infection increases. The malaria burden associated with pregnancy has an additional impact due to the effect on the health of the foetus (WHO/UNICEF, 2003, p17).

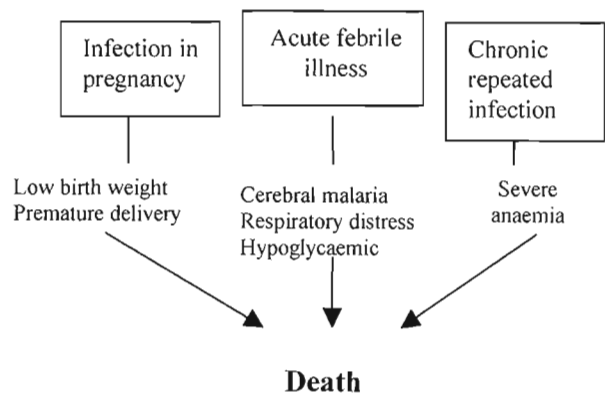
#### **2.1.1 Malaria's affects on children**

There are three principal ways in which malaria can contribute to death in young children (Figure 2.1). First, an overwhelming acute infection, which frequently presents as seizures or coma (cerebral malaria), may kill a child directly and quickly.

Second, repeated malaria infections contribute to the development of severe anaemia, which substantially increases the risk death. Third, low birth weight – frequently the consequence of malaria infection in pregnant women – is the major risk factor for death in the first month of life. In addition, repeated malaria infections make young children more susceptible to other common childhood illnesses, such as diarrhoea and respiratory infections, and thus contribute indirectly to mortality (WHO/UNICEF, 2003).

Children who survive malaria may suffer long-term consequences of the infection. Repeated episodes of fever and illness reduce appetite and restrict play, social interaction, and educational opportunities, thereby contributing to poor development. An estimated 2% of children who recover from malaria infections affecting the brain (cerebral malaria) suffer from learning impairments and disabilities due to brain damage, including epilepsy and spasticity (WHO/UNICEF, 2003, p18). The malaria burden associated with pregnancy has an additional impact due to the effect on the health of the foetus

**Figure 2.1 Malaria kills children in three different ways**



Source: WHO/UNICEF, 2003, p18

### **2.1.2 Malaria's affects on pregnant women**

Malaria infection during pregnancy is a major public health problem in tropical and subtropical regions throughout the world. In most endemic areas of Africa, pregnant

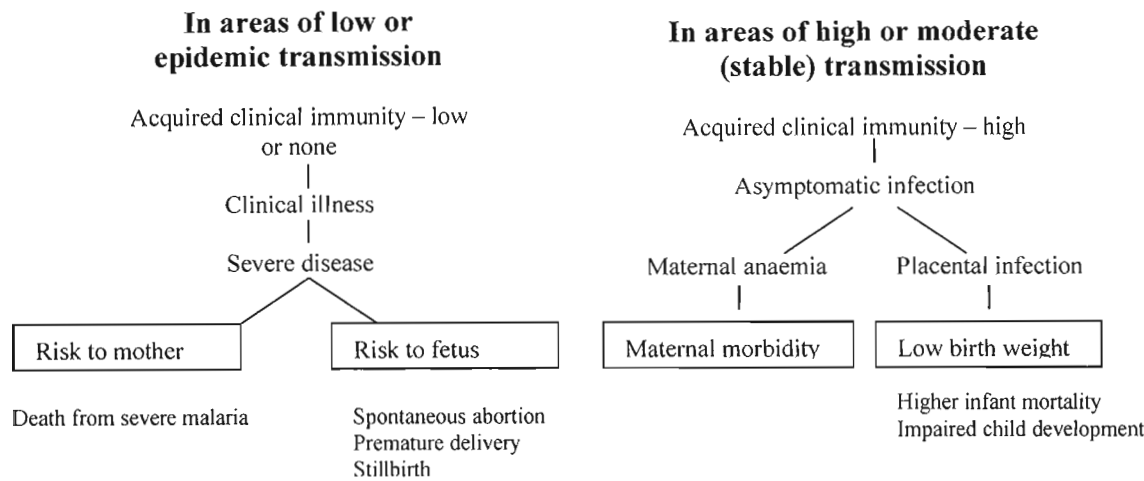
women are the main adult risk group for malaria. The main burden of malaria infection during pregnancy results from infection with *Plasmodium falciparum*. Every year at least 30 million women in malarious areas of Africa become pregnant; most of these women live in areas of relatively stable malaria transmission (WHO/UNICEF, 2003, p38).

The symptoms and complications of malaria during pregnancy differ with the intensity of malaria transmission and thus with the level of immunity acquired by the pregnant woman (WHO, 2003). Since malaria transmission intensity may vary within the same country from areas of relatively stable transmission to areas of unstable or epidemic transmission, the clinical picture of malaria infection during pregnancy may likewise range from asymptomatic to severe, life-threatening illness (WHO/UNICEF, 2003, p38).

In areas of epidemic or low (unstable) malaria transmission, adult women have not acquire any significant level of immunity and usually become ill when infected with *p. falciparum*. For pregnant women in these areas the risk of developing severe malaria is 2-3 times higher than that for non-pregnant women living in the same area. Maternal death may result either directly from severe malaria or indirectly from malaria –related severe anaemia. In addition, malaria may result in a range of adverse pregnancy outcomes, including low birth weight, spontaneous abortion, and neonatal death (Figure 2.2) (WHO/UNICEF, 2003).

In areas of high and moderate (stable) malaria transmission, most adult women have developed sufficient immunity that, even during pregnancy, *p. falciparum* infection does not usually result in fever or other clinical symptoms. In these areas, the principal impact of malaria infection is malaria-related anaemia in the mother and the presence of parasites in the placenta. The resulting impairment of fetal nutrition contributes to low birth weight and is a leading cause of poorer infant survival and development (WHO/UNICEF, 2003).

**Figure 2.2 Malaria during pregnancy**



Source: WHO/UNICEF, 2003, p38

**2.1.3 Malaria’s transmission**

The intensity of malaria transmission varies considerably and includes malaria-free areas as well as unstable and stable transmission areas. In unstable transmission areas malaria is highly seasonal and occurs for only part of the year (usually less than 6 months). These areas are prone to epidemics which can result in high levels of morbidity and mortality if not prevented or contained. There are several definitions: on malaria transmission (<http://www.malaria.org.zw/definitions.html>):

Endemic malaria

Low endemicity: a person may attain adolescence (10 years of age ) or even adulthood (20 years) before infection is acquired.

Moderate endemicity: maximum incidence occurs in childhood and adolescence. But it is not unusual for adulthood to be attained before acquiring infection.

High endemicity: by late infancy (6- 11 months) or early childhood (1- 4 years) practically all are infected, little acute illness in adolescents and still less in adults.

Hyperendemicity: most individuals acquire infection in late infancy or the second year of life. Acute manifestations are less frequent on children over five years and unusual in adults.

#### Malaria epidemic

Malaria epidemic is the occurrence of malaria cases in excess of the number expected in a given place at a given time. This unexpected increase may therefore be superimposed on the expected seasonal variations.

#### Seasonal malaria cycles

These are fluctuations in occurrence of malaria by season. The season is usually determined by rainfall in tropical areas and by temperatures in sub-tropical and temperate areas.

#### Periodic malaria cycles

These are cycles that usually last between 8 and 10 years. They are usually determined by rainfall with amplified loss of immunity occurring in periods of low rainfall and, hence, low transmission.

#### Secular trends of malaria

Long term upward or downward trends in occurrence of malaria.

#### Stable malaria

High transmission with very little variation between the years. Collective immunity in the population is high. Epidemics are unlikely.

#### Unstable malaria

Transmission levels are low and vary from year to year. Collective immunity is low. There is a high potential for epidemics.

## **2.2 Malaria in Southern Africa**

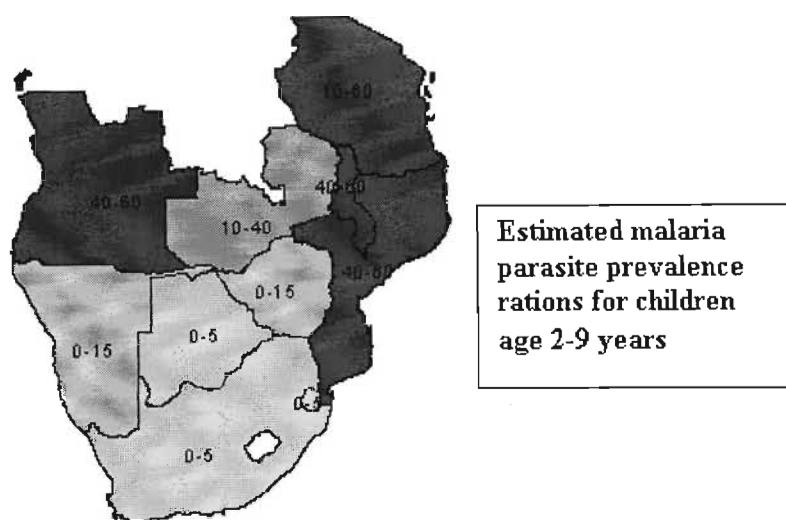
### **2.2.1 Malaria transmission in southern Africa**

Southern African countries that have unstable transmission and are particularly prone to malaria epidemics are Botswana, Namibia, South Africa, Swaziland and Zimbabwe. In stable transmission areas malaria occurs throughout the whole year and there is relatively little seasonal variation. Malaria morbidity and mortality is greatest in these areas. Countries with predominantly stable transmission are Angola, Malawi, Mozambique, Tanzania and Zambia. However, within these countries there are also areas with unstable transmission that have a high risk of epidemics ([http://www.malaria.org.zw/malaria\\_burden.html](http://www.malaria.org.zw/malaria_burden.html)).

In southern Africa, an arc can be drawn from South Africa in the south-east through Botswana and to Namibia which shows the border between malaria-free areas and unstable transmission areas. The Highveld of Zimbabwe and a few isolated upland areas (>2000m), principally in Tanzania, are also malaria-free. The division between unstable and stable transmission areas runs north along the South Africa-Mozambique and Zimbabwe-Mozambique borders and then along the northern borders of Zimbabwe, Botswana and Namibia. To the north of this line, there are also areas of unstable transmission. Such as the Northern and Southern Highlands of Tanzania, and large towns and cities ([http://www.malaria.org.zw/s\\_profile.html](http://www.malaria.org.zw/s_profile.html)).

The prevalence of malaria cases indicates the intensity of malaria transmission. High levels of malaria prevalence (parasitaemia) in children indicate intense stable transmission. In the map (Figure 2.3), it can be seen that in the stable transmission countries, malaria prevalence among 2-9 years can be as high as 60%. While in the unstable transmission countries, prevalence is considerably lower (<15%). Vector control in some of these countries (e.g. South Africa and Swaziland) has contributed to bringing malaria prevalence down to very low levels (<2%) ([http://www.malaria.org.zw/malaria\\_burden.html](http://www.malaria.org.zw/malaria_burden.html)).

**Figure 2.3 Estimated malaria parasite prevalence ratios for children aged 2-9 years in southern Africa**



Source: [http://www.malaria.org.zw/malaria\\_burden.html](http://www.malaria.org.zw/malaria_burden.html)

A number of factors affect malaria transmission in the subregion. The chief determinant is climate which affects both the life of the anopheles mosquito and the development of malaria parasites. The development of malaria parasites is great retarded below 20 Celsius and ceases to develop below 16 Celsius. In addition, relative humidity of over 60% lengthens the life of the mosquito enabling it to transmit the infection ([http://www.malaria.org.zw/s\\_profile.html](http://www.malaria.org.zw/s_profile.html)).

There are also a number of human factors that affect malaria transmission. Vector control efforts, particularly residual house spraying programme and source reduction in urban areas have made previously malarious districts malaria-free. Equally the breakdown of vector control has resulted in previously malaria-free areas such as the Zambian Copperbelt becoming malarious again. Forced and voluntary population movements affect malaria transmission, as do man-made changes to the environment. For example, urbanisation leads to source reduction while dam building – particularly in semi-arid areas - can create foci of malaria transmission ([http://www.malaria.org.zw/malaria\\_burden.html](http://www.malaria.org.zw/malaria_burden.html)).

The movement of non-immunes to malarious areas (e.g. urban migrants visiting families in rural areas, business travellers and tourists) can put individual at risk of

severe malaria. Major population movements from low to high intensity transmission areas triggered by such factors as resettlement schemes, natural disasters or conflict can cause a sharp upturn in malaria incidence and sometimes lead to epidemics. Migrants can introduce malaria (or drug resistant strains) into previously malaria-free areas. Other ways migration can affect malaria transmission are by alter its environmental conditions which facilitate or hinder transmission; and introducing new ideas and malaria control products into rural communities ([http://www.malaria.org.zw/malaria\\_burden.html](http://www.malaria.org.zw/malaria_burden.html)).

### **2.2.2 Burden of malaria on health in southern Africa**

A summary of the extent of the malaria problem on health in southern Africa is as follows: ([http://www.malaria.org.zw/malaria\\_burden.html](http://www.malaria.org.zw/malaria_burden.html)),

- ❖ Malaria is the first or second leading cause of illness and death
- ❖ Malaria is responsible for 200,000 deaths per annum
- ❖ Between 10,000,000 and 37,000,000 confirmed cases of malaria occur per annum
- ❖ The incidence of confirmed malaria is between 73 and 266 per 1000 population per annum
- ❖ The incidence of confirmed malaria ranges is between 115 and 420 per 1000 population at risk per annum
- ❖ Malaria parasitaemia among children age 2-11 years ranges from 0-5% to 40-60%
- ❖ Malaria accounts for between 3 (Swaziland) and 50% (Malawi) of outpatient attendances
- ❖ Malaria accounts for between 3% (Swaziland) and 24% (Malawi) inpatient deaths

Malaria is a major cause of mortality in Southern Africa. Of the 139 million people living in Southern Africa, approximately 63% live in malarious areas. In areas of stable transmission, the most important risk groups are under-five year olds, pregnant women and travellers who normally reside in unstable or malaria-free areas. In the predominantly stable transmission countries – Angola, Malawi, Mozambique,

Tanzania and Zambia – there are an estimated 13,678,000 under-five year olds and 3,302,000 pregnant women at risk of severe malaria. In the predominantly unstable transmission countries – Botswana, Namibia, South Africa, Swaziland and Zimbabwe - where all age groups have a high risk of malaria due to low levels of acquired immunity, it is estimated 12,382,000 people are at risk of malaria ([http://www.malaria.org.zw/malaria\\_burden.html](http://www.malaria.org.zw/malaria_burden.html))

**Table 2.1 Malaria country profile in southern Africa**

	Population	Under-five year olds	Pregnant women	Population living in malarious areas	People living in malarous areas	Under-5 year olds at risk of malaria	Women at risk of malaria
Angola	11967000	2297000	568000	100	11967000	2297000	568000
Botswana	1551000	243000	54000	40	6204000	97200	21600
Malawi	10377000	1933000	493000	100	10377000	1933000	493000
Mozambique	16118000	2836000	682000	100	16118000	2836000	682000
Namibia	1653000	261000	59000	66	1090980	172260	38940
S. Africa	44295000	5943000	1311000	10	4429500	594300	131100
Swaziland	931000	150000	34000	30	279300	45000	10200
Tanzania	32189000	5650000	1324000	90	28970100	5085000	1191600
Zambia	8690000	1536000	368000	100	869000	1536000	368000
Zimbabwe	11924000	1975000	438000	50	5962000	378500	219000
	139695000	22824000	5331000	63	88504280	15583260	3723440

Source: [http://www.malaria.org.zw/malaria\\_burden.html](http://www.malaria.org.zw/malaria_burden.html)

The consequences of malaria in pregnancy include anaemia, miscarriages, stillbirths and low birthweight. Cerebral malaria can lead to disabling neurological sequelae. Hence, among young children, an episode of severe malaria may negatively impact on their educational attainment. In stable transmission countries severe anaemia among under-fives is more common than cerebral malaria. In unstable transmission countries, cerebral malaria is the main complication of severe malaria ([http://www.malaria.org.zw/malaria\\_burden.html](http://www.malaria.org.zw/malaria_burden.html)).

### **2.2.3. Malaria and poverty in southern Africa**

The health of a nation is of primary importance to social and economic development. Within southern Africa, malaria is a major impediment to socio-economic development and an important cause of poverty.

Poverty also affects malaria. Communities with low incomes, limited education and poor access to health care are least able to engage in malaria control activities. Prevention of malaria may not be affordable nor properly understood. Equally, treatment-seeking behaviour may be influenced by lack of education as well as inability to pay transport, consultation and treatment fees at health facilities. At the same time, malaria affects poverty. In poor households, a greater proportion of income is likely to be spent on malaria treatment than in richer households, malaria illness can cause to absenteeism from work and school, poor scholastic performance, lack of labour for cultivation, and a decline in child care; malaria deaths can lead to funeral costs, loss of an income-earner and a rise in orphanhood. Hence, a negative spiral can develop with malaria causing and deepening poverty which, in turn, exacerbates inequalities in society. Malaria-poverty linkages may exist both in poor rural communities as well a peri-urban settlements ([http://www.malaria.org.zw/malaria\\_burden.html](http://www.malaria.org.zw/malaria_burden.html)).

Poor people are at increased risk both of becoming infected with malaria and of becoming infected more frequently. Child mortality rates are known to be higher in poorer households and malaria s responsible for a substantial proportion of these deaths. Poor families live in dwellings that offer little protection against mosquitoes and are also less likely to be able to pay either for effective malaria treatment or for transportation to a health facility capable of treating the disease. Both direct and indirect costs associated with a malaria episode represent a substantial burden on the poorer households. A study in northern Ghana found that, while the cost of malaria care was just 1% of the income of the rich, it was 34% of the income of poor households. Moreover, in epidemic-prone countries, malaria epidemics are likely to be most severe in the poorest communities ([http://www.malaria.org.zw/malaria\\_burden.html](http://www.malaria.org.zw/malaria_burden.html)).

#### **2.2.4 Malaria burden on health expenditure in southern Africa**

Within the Ministry of Health, malaria uses up resources for its prevention and control. In addition, expenditure on insecticides, drugs, equipment etc. and large numbers of malaria patients may lead to health facility staff being stretched beyond capacity, thereby reducing the standard of care received by all patients. Malaria also exerts a major burden on other Government ministries, notably education (<http://www.malaria.org.zw/economics.html>).

Malaria is responsible for a high proportion of public health expenditure on curative treatment, and substantial reductions in malaria incidence would free up available health resources and facilities and health workers; time, to tackle other health problems. (WHO/UNICEF, 2003)

#### **2.2.5 Malaria's economic burden**

Malaria impacts on the economy at a number of levels including within households and communities, the private sector, government and the macro economy (<http://www.malaria.org.zw/economics.html>).

Malaria in the household may lead to:

- ❖ Absenteeism from work or school
- ❖ Important domestic jobs such as cultivation of crops and water/food gathering may be neglected
- ❖ Reduced household income
- ❖ Reduced household expenditure on food
- ❖ Increase in nutritional deficiencies
- ❖ Children taking off school to care for family or earn money
- ❖ Reduced expenditure on school fees
- ❖ Under performance at school and lack of achievement of personal potential
- ❖ Increased financial and time costs of attending health centres and buying drugs
- ❖ Increased numbers of orphans and foster children
- ❖ Long term losses in household productivity in the case of mortality

#### ❖ Funeral costs

Malaria affects the productivity of the private sector. Key businesses that are particularly affected by malaria are likely to include agriculture, tourism, mining and construction industries. The private business sector may be adversely affected by the problems of a sick workforce. The level of productivity may decline (especially in agriculture if an epidemic coincides with harvest or planting time) and the costs of providing sick pay (if it is paid) will rise. The cost of private healthcare provided by employers may also rise dramatically. In short, profits will be eroded.

A government is responsible for the health and wellbeing of its people, rising malaria costs can have the following effects:

- ❖ Use up funds that could be employed in other important areas to benefit the country
- ❖ Drain the health care resources
- ❖ Reduce revenue available to the government, e.g. sickness leads to lower earnings and expenditure and thereby to lower tax revenues
- ❖ Place great pressure on health workers
- ❖ Reduce the standard of care to non-malaria patients
- ❖ Reduce private sector profits caused by declining productivity

Poverty and inequalities are exacerbated, government resources come under increasing pressure, and the private sector faces reduced investment, growth, profits and inflow of foreign currency. Together, this will result in a decline in gross domestic product and socio-economic development being hindered.

#### **2.2.6 Recent trends of malaria in southern Africa**

Major trends over the last few decades point to a worsening situation if effective action is not taken. These trends include: an increase in epidemic malaria; upward trends in mortality over the last three decades, including in sub-Saharan Africa; an upward trend in drug-resistant *p. falciparum* malaria; the re-emerge of *p. vivax* malaria in areas from where it had been previously eradicated e.g. Caucasus and

Central Asia; and increase in imported malaria in the developed world ([www.who.int/tdr/diseases/malaria/](http://www.who.int/tdr/diseases/malaria/)).

In southern Africa, qualitative reports as well as surveillance data indicate that malaria deaths are rising in some countries (Namibia, South Africa, Zimbabwe). Malaria mortality in under-5s almost doubled in eastern and southern Africa over the period 1990-1998 compared with 1982-1989. It is likely to be due to a combination of factors including late-treatment seeking behavior, quality of care, inadequate transport and communication for referral systems to function properly, the improved coverage of Health Information System (HIF) and misdiagnosis due to a general rise in fevers associated with HIV. However, the main reasons for this are likely to include deteriorating health sectors within the subregion, a breakdown in malaria control efforts, rising drug and insecticide resistance, population movements and environmental changes favouring malaria transmission. It is known that the prevalence of malaria infections caused by chloroquine-resistant parasites increased substantially from the late 1980s in these same areas. Thus, although the methodology cannot prove cause and effect, it is very likely that some of this increase in child mortality was related to some extent to the spread of chloroquine-resistant malaria ([http://www.malaria.org.zw/malaria\\_burden.html](http://www.malaria.org.zw/malaria_burden.html)).

Consequently, within Southern Africa, there is need to increase investment in malaria control as well as to understand, investigate and mitigate the relationships between malaria and socio-economic development. Improvements in access to primary health care and primary school enrolment in Southern Africa are likely to have increased the ability of the poor to prevent and control malaria.

### **2.3 Malaria eradication and malaria control: a brief history**

Soon after the Second World War the World Health Organization recognised that malaria not only killed more people than any other disease but also interfered with the development of agriculture and industry. The advent of DDT presented the world with a new method of interrupting the transmission of malaria infection by attacking the adult anopheles vector during its epidemiologically most important stage, when it

feeds on man in his dwelling or when it shelters indoors in the nearest house or animal shelter.

The worldwide programme of malaria eradication was formally endorsed by the Eighth World Health Assembly in 1955 and in 1957 the WHO took over the coordinating activities and the provision of technical assistance. The malaria eradication programme has been defined as an operation aimed at cessation of transmission of malaria and elimination of the reservoir of infected cases in a campaign limited in time and carried to such a degree of perfection that, when it comes to an end, there is no resumption of transmission (Leonardo, 1980).

The global malaria eradication campaign had succeeded in increasing the population freed from malaria transmission from 400 million to 1200 million. By the early 1970s malaria had been eliminated from the whole of Europe, the Asian part of the USSR, several countries of the Near East, most of North America including the whole USA, most of the Caribbean, large areas of the northern and southern portions of South America, Australia, Japan, Singapore, Korea, Taiwan and China (Leonardo, 1980). However, many countries in Africa lacked the infrastructures and resources necessary to mount sustainable campaigns against malaria and as a result few benefited from historical efforts to eradicate malaria ([http://www.rbm.who.int/cme\\_upload/0/000/015/370/RBMInfosheet\\_3.htm](http://www.rbm.who.int/cme_upload/0/000/015/370/RBMInfosheet_3.htm)).

After two decades of this unique international endeavour in the field of public health, the overall results are of great interest; yet they show that under some conditions it cannot be put into practice. Because of serious technical problems (multiple resistance of vectors to insecticides and drugs to anophelids, exophilic behaviour of vectors, or population migration), administrative limitations (in financial resources or organisation structure), or the consequences of natural disasters (earthquakes, cyclones, or floods), there is a need of long-term malaria control programme that reflect its very nature of flexibility, adaptation to variable epidemiological conditions, dependence on social, administrative, and even political conditions (Leonardo, 1980).

The differences between malaria control and malaria eradication are given in Table 2.2.

**Table 2.2 Differences between malaria control and eradication**

	Control	Eradication
Objective	Reduction of incidence until no longer a major public health problem	Cessation of transmission and elimination of the human reservoir of infection
Duration	Indefinite	Limited in time
Area of operation	Only where transmission is intense	All areas where transmission occurs
Total coverage (by spraying and surveillance)	Not necessary	Indispensable
Operational standards	Good	Perfect
Cost	Recurring	Capital investment; after completion no recurring annual cost except for surveillance
Assessment of results	Sampling of population for parasite rates and spleen rates (malariometric surveys)	Case detection (active and passive) in advanced stages. Surveillance procedure
Imported cases	Not relevant	Of concern in advanced stages of the programme

Source: Bruce-Chwatt, (1980, p281).

Thirty years after the abandonment of the first ‘global’ campaign to eradicate malaria, the disease is again high on the international health agenda. In 1992, malaria control was re-established as a global health priority by a Conference of Ministers of Health held in Amsterdam. In 1998, Roll Back Malaria (RBM) was founded as a global partnership by the World Health Organization (WHO), the United Nations Development Programme (UNDP), the United Nations Children’s Fund (UNICEF) and the World Bank with the goal of halving the world’s malaria burden by 2010. The RBM partnership includes national governments, civil society and non-governmental organizations, research institutions, professional associations, UN and development

agencies, development banks, the private sector and the media  
([http://mosquito.who.int/cgi-bin/rbm/dhome\\_rbm.jsp?ts=3238061358&service=rbm&com=gen&lang=en&type=intro&channelId=-8254&chLevel=2&p=rbminitiative](http://mosquito.who.int/cgi-bin/rbm/dhome_rbm.jsp?ts=3238061358&service=rbm&com=gen&lang=en&type=intro&channelId=-8254&chLevel=2&p=rbminitiative)).

Tackling malaria effectively requires substantial resources. At the Roll Back Malaria Abuja Summit in 2000, it was estimated that at least US\$ 1 billion is needed from a combination of increased domestic spending and international assistance. Since the launch of RBM in 1998, international spending on malaria has more than doubled to approximately US\$ 200 million per year. However, the finance resources for fighting malaria are increasing. The establishment of the Global Fund to Fight AIDS, Tuberculosis and Malaria is providing significant new grants to help countries accelerate implementation of their plans to Roll Back Malaria. In addition, funds made available to improve health under debt-relief initiatives are being used to finance malaria interventions in some countries. (WHO/UNICEF, 2003)

Southern African Malaria Control (SAMC) was set up in 1997, by the World Health Organization, to spearhead the fight against malaria in Southern Africa (Angola, Botswana, Malawi, Mozambique, Namibia, South Africa, Swaziland, Tanzania and Zimbabwe) (<http://www.malaria.org.zw/samc.html>)

## **2.4 Malaria Control in Southern Africa**

Southern Africa has a long history of malaria control going back over 50 years. Malaria is accepted as national and regional public health priority in Southern Africa. Today, Angola, Botswana, Malawi, Mozambique, Namibia, Swaziland, South Africa, Tanzania, Zambia and Zimbabwe have established or are establishing malaria control units and programmes at national levels. Small scattered malaria projects in different areas are slowly being integrated and co-ordinated into national programmes to cover all populations in malarious areas. However the priority tends to be higher in countries such as Botswana, Namibia, Zimbabwe, South Africa and Swaziland where unstable malaria with annual and cyclical epidemics caused alarm and crises. Unfortunately malaria as a priority appears low in stable endemic countries (Zambia, Malawi, Tanzania) where chronic malaria with a higher but less dramatic burden

continues to be accepted as a problem to live and die with. In Angola, there are conflicting priorities for basic survival following 35 years of armed conflict ([http://www.malaria.org.zw/public\\_mgt.html](http://www.malaria.org.zw/public_mgt.html)).

Success has been achieved in southern Africa in establishing malaria free areas and reducing the level of infection and reducing deaths from malaria in some countries. However, there is still a great challenge for national malaria control programs to widen their activities and coverage on an annual basis for the next 10 – 20 years to ensure that all people at risk of malaria have insecticide soaked bed nets or sprayed homes, and can reach and be diagnosed and treated quickly for malaria with drugs in the community, or at a health centre or hospital ([http://www.malaria.org.zw/public\\_mgt.html](http://www.malaria.org.zw/public_mgt.html)).

#### **2.4.1 Malaria control methods**

Malaria control methods vary from the simplest to the most elaborate but the success of the former or the failure of the later are equally likely if they are applied without careful consideration of the local problem to determine the best solution in the light of available knowledge.

The classification of malaria control measures in relation to the chain of infection includes those that aim at the prevention of the contact of man with the *Anopheles* vectors or at the reduction of the vector population in its larval or adult form. Finally chemotherapeutic means are designed to eliminate malaria parasites in the human host. Most of these measures can be also considered from both the individual and collective angles. Malaria control measures are summarized in Table 2.3.

**Table 2.3 Classification of malaria control measures**

Type of measures		Individual protection	Community protection
Prevention of man/ vector contact		Repellents, protective clothing, bed-nets/insecticide-treated nets, screening of houses	Site selection, screening of houses
Vector control	Destruction of adult Anopheles vectors	Use of domestic space sprays including aerosols	Space spraying, ultra low volume sprays, residual insecticide spraying
	Destruction of mosquito larvae	Peri-domestic sanitation, intermittent drying of water containers	Larviciding of water surfaces, intermittent drying, sluicing, biological methods
	Source reduction of mosquitoes	Filling, small scale drainage and other forms of water management	Prevention of man-made malaria, environmental sanitation, water management, drainage schemes, naturalistic methods of control
Measures against the malaria parasites		Diagnosis and early home treatment, chemoprophylaxis	Diagnosis and early treatment for outpatient (malaria) and inpatient (severe malaria), mass drug administration for pregnant women, traveller, and migrants.
Social participation		Motivation from personal and family protection	Community involvement, health education, expansion of rural health services. Training of staff

Source: Bruce-Chwatt (1980, p274)

**2.4.2 Malaria control strategy**

RBM suggests a number of evidence-based, cost-effective interventions which, if brought to scale in malaria-endemic countries, could have a significant impact on both morbidity and mortality from malaria. These are including:

- ❖ Early diagnosis and prompt, effective treatment of malaria
- ❖ Prevention of malaria through use of insecticide-treated materials and other vector control measures including residual indoor spraying, larviciding and environmental management
- ❖ Early detection and prevention of epidemics, and rapid response to epidemics (through monitoring, surveillance, preparedness, timely action).
- ❖ Development of new tools, strategies and methodologies, and improvement in delivery of existing tools through research and development
- ❖ Coordinated action through establishing partnerships that utilize an optimal mix of measures adapted to local situations  
([www.who.int/tdr/diseases/malaria/](http://www.who.int/tdr/diseases/malaria/))

In southern Africa, the national malaria units and programs have to struggle to maintain a critical presence within changing and unstable health systems within the current health reform and sector wide process. The critical issues being how to create and maintain malaria as a priority health problem and ensure health policy support and develop health systems and malaria control systems to rapidly scale up and effectively and equitably deliver access, coverage, quality and impact with the available malaria control tools (diagnostics, drugs, ITNs, house spraying) through a health delivery system and to sustain continuing high levels of coverage.

## **CHAPTER 3 AN OVERVIEW OF COST-EFFECTIVENESS ANALYSIS**

Economic evaluation could make substantial contribution to malaria control decision-making. Disease gives rise to an economic burden on individuals and governments, and disease reduction can therefore produce savings in resources. Since, resources are scarce, putting money into one activity is always at the expense of not doing something else, and as a result, simply knowing that we have an intervention that works is not sufficient to decide to spend money on it, policy-makers must compare the costs and effectiveness of the intervention, with the costs and effects of additional investment in other services.

### **3.1 Alternative Evaluation Methods**

The techniques of economic evaluation are based on the economists' concern with economic efficiency and opportunity costs and of an important contribution to the methods of health service evaluation. Economic evaluation studies generally seek to address the two questions: are limited resources used in the best ways possible? Is value for money achieved in their use?

Economic evaluation has been defined as 'the quantitative analysis of the relative desirability to the whole community of investing in alternative projects or programmes', where desirability is assessed in terms of both costs and consequences (Mills, 1988). 'Consequences' is used here as the generic term for the beneficial results of a programme (often termed effects or benefits, depending on the techniques of analysis being used). Within this broad definition there are many forms of economic evaluation, as shown in Figure 3.1. Only those forms which examine both costs and consequences for two or more alternatives fit the above definition and can be described as full economic evaluation studies. In practice, one of the two alternatives examined may be an existing project/programme (the 'do-nothing' alternative).

**Figure 3.1 Forms of economic evaluation**

		Are both costs and consequences examined?		
Is there a comparison of 2 or more alternatives?	No	No		Yes
		Examines consequences only	Examines costs only	Cost-outcome description
		Outcome description	Cost description	
	Yes	Effectiveness evaluation	Cost analysis	<ol style="list-style-type: none"> <li>1. Cost minimization analysis</li> <li>2. Cost effectiveness analysis</li> <li>3. Cost benefit analysis</li> <li>4. Cost utility analysis</li> </ol>

Source: Drummond et al, 2001.

Cost-minimisation analysis (CMA) (Mills, 1988) is based on prior epidemiological findings which show that the outcome of interest (e.g. reduction of disability) is achieved to the same degree by two (or more) interventions. The technique is used to identify the least cost intervention.

Cost-effectiveness analysis (CEA) investigates the best way of achieving a single objective by comparing effects and costs. It evaluates either:

- ❖ which of a number of possible interventions will achieve a given health objective at least cost, or
- ❖ given a fixed budget, the intervention that maximises the effectiveness of the expenditure.

Its results are expressed either as costs per unit of output (total costs of the intervention divided by total health effect) or as effect per monetary unit (total health effect divided by total available resources).

Cost-benefit analysis (CBA) (Mills, 1988) values both costs and benefits in monetary terms, and compares them, assessing whether the project/programme is desirable through the use of decision criteria (e.g. if the benefit cost ratio (benefits divided by costs) is greater than one, the project/programme is worthwhile).

Cost-utility analysis (CUA) (Mills, 1988) is a form of CEA but it measures the effects of a project/programme in terms of utilities (the quality-adjusted health outcome caused or averted). Like CEA it can focus on either minimizing cost or maximizing effects; and its results are expressed, for example, in terms of costs per Quality Adjusted Life Year (QALY) or QALYs per monetary unit.

The root differences between these techniques concern their evaluation of health outcome (consequence) and their breadth of analysis (dimensions of objectives). A cost-minimization analysis can only be carried out without ambiguity if it is based on existing medical evidence of effectiveness. However, if the effectiveness evidence were to be generated at the same time as the costs, one would not know in advance whether equivalence in effects would be obtained. Therefore, the *ex ante* design for these studies is usually CEA. On some occasions the study may require to assess

multiple dimensions of effectiveness. And, normally CUA is more appropriated than the others. The comparison of the differences among CMA, CEA, and CUA is summarised in Table 3.1. The nature of economic evaluation of malaria preventive programmes in terms of consequences and their breadth of analysis is also presented in Table 3.1, and indicate that CEA is the best match.

**Table 3.1 CMA, CUA and CEA comparison and the nature of economic evaluation of malaria preventive programmes**

	Objectives	Effectiveness
CMA	Multiple dimensions	Non-change effectiveness
CUA		Effectiveness may change along with costs
CEA		Effectiveness may change along with costs
Malaria preventive	Single goal	Effectiveness may change along with costs

CBA is broader in scope than CEA/CUA given that CBA converts all costs and benefits to money, it is not restricted to comparing programmes within health care, for example, but can also be used to inform resource allocation decisions between sectors of the economy (Drummond 2001). In contrast, CEA/CUA is necessarily restricted to programmes that produce similar units of outcome such as DALYs. However, the difficulties in assigning a monetary value to human life or quality of health outcome make CBA cumbersome when applied to health care programmes. Therefore, the less complex CE is preferred for health programme evaluations, in which the results are explicitly stated in terms of health outcomes rather than money. The differences between CBA and CEA/CUA are summarised in Table 3.2 below.

**Table 3.2 CBA and CEA/CUA comparison**

	Objectives	Costs measure	Benefits measure
CBA	Single dimension and multi-dimensions	Monetary unit	Monetary unit
CEA/CUA	CEA: single dimension CUA: multi-dimensions	Monetary unit	Costs per unit output or effects per monetary unit

### 3.2 Cost-Effectiveness Analysis

It is important to specify the form of evaluation and to outline an analysis plan in advance, for which the following rules of thumb (Drummond et al, 2001) should be of some help:

- ❖ Take time to clarify the objectives of the programme or treatment.
- ❖ If one major dimension for the measurement of success is apparent, perform a cost-effectiveness analysis based on this dimension (or perform a cost-minimization analysis if it turns out that the alternatives have equivalent effectiveness on the chosen dimension.)
- ❖ Look for other attributes of the alternatives being assessed, even if the medical research design does not consider these formally. Where possible, record the effectiveness of the alternatives as judged on these extra dimensions and be prepared to mount ad hoc surveys to obtain more information
- ❖ Keep open the possibility of employing more sophisticated forms of analysis if it turns out that there is more than one appropriate dimension for judging effectiveness.

With respect to malaria preventive programmes, it is clear that the appropriate economic evaluation technique is CEA. CEA is most useful when the interventions being compared have a clear and specific outcome. CEA is most suited, then, to scenarios such as

1. Comparing alternative strategies of an identical goal
2. Identifying which intervention method is best for a specific population
3. Providing empirical support for the adoption of previously underfunded programs with low cost-effectiveness ratios
4. Identifying practices that are not worth their cost (Getzen, 1997)

The malaria preventive programmes mainly concern one clear objective - preventing malaria occurrence - although there may have some other effects. Therefore cost-effectiveness analysis is the appropriate method by which to evaluate alternative malaria prevention programmes. Cost-utility analysis and cost-benefit analysis are too complicated in the purpose of the programmes analysis.

### 3.3 The CEA Procedure In Summary

The major steps of cost-effectiveness analysis are summarized as following (Shepard and Thompson, 1979):

1. Define the programme
  - ❖ Develop alternative approaches to problem
  - ❖ Define precisely programmes to be analysed (who, what, where, why, when, and how)
2. Compute net costs
  - ❖ Compute gross programme costs
  - ❖ Compute monetary savings
  - ❖ Discount costs and savings to present value.
  - ❖ Compute net costs (gross costs less savings)
3. Compute net health effects (in terms of additional years of healthy life)
  - ❖ Add
    - Additional years with full health,
    - Additional years of disease,
    - Improvement in health (no extension of life),
    - Negative effects (inconveniences and morbidity)
  - ❖ Modify by time preference factors
4. Apply decision rules
  - ❖ Identify case based on signs of net costs and net effects
  - ❖ Apply rule for appropriate case
5. Perform sensitivity analysis
  - ❖ Vary uncertain parameters and recomputed costs and health effects.
  - ❖ Examine effects on decision

### **3.4 CEA Applied To Health Programmes: Some Examples**

Cost-effectiveness analysis is a very useful approach where there is a single unambiguous objective of health programmes. CEA is a common economic evaluation tool in selection between prevention and treatment for infectious diseases. With regard to HIV/AIDS, the common effectiveness of HIV/AIDS interventions, whether the intervention is prevention, treatment or care, could be easily identified as death averted, HIV infection averted or disability adjusted life year gained (Creese et al, 2002; Bos et al, 2001). It's also common to see CEA used in health programme selection for tuberculosis (Migliori, et al, 1998), hepatitis (Zhou et al, 2003; San et al, 2003), and etc., with similar outcome measures of death averted, infection averted or disability adjusted life year gained.

CEA is also often seen for selection of various interventions for cancer treatment (e.g., Monz et al, 2003; Ladabaum et al, 2003; Mahadevia et al, 2003). The outcome measures usually identified as life year gained, discounted life year gained and quality life year gained. It has been seen that antidepressant programme used CEA to compute cost-effectiveness with outcome measure of cost every 10% chance of response (Kim et al, 2003), acute migraine treatment with cost per attack treated (Wells et al, 2003), schizophrenia and persistent auditory hallucinations with cost per patient (Stant et al, 2003) and various other diseases interventions, such as pharmacotherapies for Parkinson's disease (Coyle et al, 2003) and treatment for osteoporosis (Johnell et al, 2003), etc. Further, comparison of Hospital at Home and in-patient interventions could use CEA framework with outcome measure of cost per treatment day (Jester et al, 2003).

### **3.5 Some Limitations Of CEA**

With cost-effectiveness analysis, some limitations and difficulties of the method should be noticed. The most salient practical problem in performing cost-effectiveness analysis is the lack of adequate data. Definitive data on the likely health effects of preventive programmes are rare, and cost data, too, are often insufficient. While this problem complicates and reduces the precision of cost-effectiveness analysis, it may

paradoxically increase the attractiveness of performing this analysis. Many important decisions cannot wait until ideal data are obtained. Compared with alternative processed for decision-making – for instance, cost-benefit analysis or intuition- cost-effectiveness analysis is better able to cope with data problems because CEA avoids the difficult problems of money valuation. Moreover, CEA provides a framework for using the available objective data and the subjective estimates of experts.

Representative experts or consumers can be polled and ranges of values considered. A weakness of cost-effectiveness analysis, therefore, is that it rarely yields a single, definitive answer. Its partly compensating advantage is that assumptions are made explicitly and their effect on the analytic results is made clear.

A related weakness is the practical difficulty of incorporating consumers' input into an analysis. In theory, the method can incorporate the preferences of any representative consumer in evaluating alternative programmes. Valuations of quality of life can be made by past, current, or prospective recipients of a treatment. Because these values are shown explicitly, the resulting analysis can be scrutinized to assure that these preferences, and expert opinions, have been interpreted correctly. With a sensitivity analysis, the opinions of many experts and the values of many consumers can be incorporated. Undoubtedly, however, analysts will need patience and sensitivity to elicit preferences that are expressed in a usable manner, and consumers may require examples and nontechnical explanations before accepting any numerical analysis.

### **3.6 Differences Between Evaluation Studies**

This review aims to look at studies of cost-effectiveness analysis for malaria prevention programmes. These studies have a common framework:

- ❖ Objectives: compares the effectiveness and cost-effectiveness of preventive programmes against malaria infection in concern of populations and/or highly affected area
- ❖ Questions being answered: assess whether and in what circumstances costs are associated with the better gain in outcome from malaria preventive alternatives;

test the sensitivity of the results to the use of different means of the malaria preventive programmes.

- ❖ Data analysis methods: normally are within cost-effectiveness analysis framework, may associated with scientific statistic data analysis.
- ❖ Conclusion: provide guidelines for the provision of preventive services

The procedures may differ between studies. Different economists may use different approaches in conducting cost-effectiveness analysis. For instance, Mills et al (1988) suggest three basic steps, while Haddix et al (1996) suggest nine basic steps. Other differences may include the following:

The way of settling direct costs and indirect costs – what is included, what is not?

Different measures of health effectiveness: effectiveness measures used in malaria prevention programmes include costs per death averted (DA), cost per disability adjusted life year (DALY), cost per sick child averted, etc. This will lead to some difficulties in comparing studies.

## **CHAPTER 4 A REVIEW OF COST-EFFECTIVENESS ANALYSES OF MALARIA PREVENTION**

### **4.1 Identification Of Studies For Review**

Using the Academic Search Premier of EBSCO information services, the world's largest academic multi-disciplinary database, a comprehensive literature research was performed to identify published cost-effectiveness analyses (CEA) of malaria prevention in Africa context. Bibliographies of articles identified are also examined to find additional reports. Only studies published from 1999 up to the mid of 2003 that used African data and contained a health outcome measure are included in the current review (CEAs of malaria prevention conducted before had been included in a comprehensive CEA review of malaria control in Africa by Goodman et al 1999a). Five studies are identified on the cost-effectiveness analysis of malaria prevention in Africa context (Table 4.1). The interventions are included insecticide-treated nets (ITN), residual house spraying (RHS), hypothetical chemoprophylaxis for infants and environmental management (EM). CEAs of ITN included 1 from trial setting and 2 from programme settings. There was only one CEA on each intervention of RHS, chemoprophylaxis for infants and EM. One study provided CEAs both of ITN and RHS. The CEAs of RHS and EM were from programme settings. Since 1999, malaria prevention CEAs of programme settings have increased. Programme settings have merit of being realistic reflections of compliance rate of all interventions and retreatment rate of ITN. In the former review (Goodman et al, 1999a) of 11 CEAs on malaria prevention, only one was from a programme setting. In addition, one study was identified which quoted incremental cost-effectiveness ratios (Goodman et al, 2001). The study provides useful information of effectiveness and cost-effectiveness comparison of ITN and RHS, but the results cannot be compared with those for other interventions.

The studies are presented in Table 4.2 and 4.3 at the end of this chapter. This required a number of adjustments and recalculations to put them into comparable form.

**Table 4.1 Summary of cost-effectiveness analyses of malaria prevention in sub-Saharan Africa, 1999-2003**

Reference, area studied and study year	Interventions evaluated	Study type	Outcome measure used
Gonzalez, et al, 2000 (based on Menendez et al 1997) Tanzania, 1996	Chemoprophylaxis	Hypothetical interventions delivered based on controlled trial study	Cost per child protected Cost per DALY*
Goodman et al., 2001 South Africa, 1998-1999	Insecticide-treated nets	Controlled trial	Incremental case averted Incremental cost per case averted Incremental cost per death averted
Guyatt et al., 2002 Western Kenya, 2000	Insecticide-treated bets Residual house spraying	Programme evaluation	Case averted Cost per person protected Cost per infection case prevented
Hanson et al., 2003 Tanzania, Jul 1996-Jun 2000	Insecticide-treated nets	Programme evaluation	Death averted Cost per death averted Cost per DALY
Jurg Utzinger, et al, 2001 Zambia, 1929-1949	Environmental management	Programme re-analysis	Cost per malaria attack averted Cost per death averted Cost per DALY
Wiseman et al., 2003 Western Kenya, Jan 1997 – Mar 1999	Insecticide-treated nets	Controlled trial	Death averted Cost per person protected Cost per death averted Cost per life year gained Cost per *DLYG Cost per sick child visit averted

\* DALY = disability adjusted life year; DLYG = discounted life year gained

## 4.2 Insecticide-Treated Nets

Insecticide-treated net (ITNs) is a promising tool for reducing the morbidity and mortality from malaria in endemic areas, especially when associated with effective case-management practices (WHO 1996). Bednets are treated with a residual insecticide, such as permethrin, which repels and kills mosquitoes and so inhibits their feeding on humans. The efficacy of insecticide-treated nets (ITN) for the control of

malaria in Africa, especially in children less than five years of age, has been demonstrated by four large-scale randomised controlled trials (D'Alessandro et al. 1995a; Binka et al. 1996; Nevill et al. 1996; Habluetzel et al. 1997). The reduction in overall mortality in children ranged from 15% to 33% has been recorded across a range of malaria transmission intensities. A meta-analysis (Choi et al, 1995) measured the incidence of infection from 10 field trials provided pooled incidence rate ratios of infection among study groups. For the studies comparing insecticide-treated bednets with untreated bednets, the summary incidence rate ratio for acquiring malarial infections was 0.757, representing a reduction of 24%. For the studies comparing permethrin-treated bednets with controls without bednets, the summary incidence rate ratio was 0.497. Insecticide-treated nets are effective in preventing malaria, decreasing the incidence rate ratio by approximately 50% in field trials performed to the date of the study. And another meta-analysis (Lengeler 1998) found an overall estimate of protective efficacy of 19%.

In addition, economic evaluations of these trials have shown the use of ITNs to be relatively cost-effective, with a cost per discounted year of life saved ranging from US\$ 9 to \$77, and a cost per death averted ranging from \$219 to \$2959 (in 1995 prices) (Picard et al. 1993; Binka et al. 1997; Aikins et al. 1998; Some 1998; Goodman et al. 1999).

Whilst nets normally last for several years, the efficacy of the insecticide gradually wears off over time, so it is necessary to retreat the nets regularly. Implementation remains very limited in sub Sahara Africa (SSA). Whilst many small-scale projects have been established, only the Gambia runs a national programme for net treatment (Goodman et al, 1999a). Recent survey data showed that approximately 15% of young children slept under a net, but that only about 2% are nets that were treated with insecticide. Untreated nets provide some protection against malaria, but their full protective benefits can be realized only if they are regularly retreated with insecticide (WHO/UNICEF, 2003).

There are four more CEAs of ITN found in Africa context since 1999, after the CEA review of malaria interventions in Africa done by Goodman et al (1999a), which included six CEAs of ITN available up to the end of 1998. Two CEAs were

conducted alongside the trials, in the South Africa and Kenya (here called Kenya 1). Another two evaluated malaria control programmes using social marketing in Kenya (Kenya 2) and Tanzania. The costs of studies all included nets and insecticide. However, two trials were using public sector delivery mechanism for nets delivery and communal net treatment, whilst the other two were using a similar social marketing approach. The studies in Kenya and Tanzania used a discount rate of 3% for capital costs, compared with 5% for the South Africa study.

#### **4.2.1 Differences in study settings and assumptions**

Study settings and assumptions have important effects on the outcomes. The major differences of the settings and assumptions among these four studies are:

- a) two CEAs used programme setting, which used social marketing approach and had big influence on both effects and cost structure, in turn had big influences on the outcomes of studies, and the remaining two used trial condition;
- b) the useful life of nets: the South Africa one used 4 years, and the remaining used 5 years;
- c) the retreatment frequency: Kenya 1 used twice a year, and the remaining used once a year;
- d) the discount rate of the base case of South African one used 5.3%, which was the true interest rate at the time, and the remaining used 3%;
- e) insecticide and dosage of insecticide: Kenya 1 used Permethrin, and others used combinations of permethrin and pyrethroid (deltamethrin) with quite different dosage. Synthetic pyrethroid (deltamethrin) is cheaper and longer lasting than permethrin, and could make difference in the results.

Details of the study settings are summarised in Table 4.2.

#### **4.2.2 Differences in results settings and outcome measures**

Tanzania and Kenya 1 give results on two age groups of infants and children less than 5. The other two consider no specific age groups. The outcome settings, Tanzania and

Kenya 2 give gross outcomes; Kenya gives net outcomes, which take into account of savings to the health sector, households and funeral costs, and gives outcomes with community effects, which are defined as the effects on cost-effectiveness of the protection afforded to those who do not use ITNs who live in proximity (<300 meters) to households with ITNs; the South African study gives incremental gross outcome compared with residual house spraying (RHS), and incremental net outcome which take into accounts of savings of health sector, and households. The outcomes of the South African study are not readily comparable with other studies. The measures were given differently in each study. Tanzania gave DA and DALY; the key measures of Kenya were DA and cost per sick child visit averted; and Kenya 2 used per infection case prevented. The outcomes of these studies used US\$ of different years, but this is not considered important over the short period under study.

#### **4.2.3 Adjusted comparable outcomes**

To be able to compare these results, the gross outcomes are presented in different age groups as prevention in infants, prevention in childhood and prevention with no specific age group, and are summarised in Table 4.3. Several adjustments have been made to have consensus assumptions of five years useful life of nets, retreating nets once a year with capital cost discount rate at 3%. These adjustments are made by recalculating gross outcomes from the initial date of Kenya 1 (Appendices 1 & 2) and using results from sensitivity analyses. Also, the Tanzania study provided effects of malaria prevention for infants without giving the CE ratios for the age group. The current study makes it available and in Table 4.3, along with other comparable results.

#### **4.2.4 Cost-effectiveness of ITNs**

Two CEAs were conducted on ITNs in different study settings. Kenya 1 was from trial in the area subject to intense, perennial malaria transmission in western Kenya with net outcomes which included savings of health sector, households and funeral costs, and net outcomes with community effect, which included the effect of protection afforded to those who do not use ITNs who live in proximity (<300 metres)

to households with ITNs. The gross outcomes of Kenya 1 are calculated in Appendix 1, and the adjusted comparable gross outcomes, which adjust retreatment twice a year to once a year, are detailed in Appendix 2. The Tanzanian study was from a programme sponsored by KINET to explore the impact on cost-effectiveness of social marketing delivery mechanism, where the area was also subject to intense, perennial malaria transmission, and gave gross outcomes.

For infants, the death averted (DA) of Kenya 1 adjusted to gross cost (Appendix 1) with retreatment annually (Appendix 2) was 1996US\$ 2019, compared with Tanzania 2000US\$ 2879 (The study results included 2 age-groups of infants and 1-4 year-old. The recalculations of cost per DA and DALY for infants are in Appendix 3). The cost per DALY of Tanzania study is recalculated as 2000US\$ 111 (Appendix 3). Number of deaths averted in 1-11 months infants, Tanzania reported was 52 with 65111 nets sold, compared with Kenya 1 of 61 with 45667 nets distributed. The Tanzanian study had lower levers of cost-effectiveness than Kenya 1. However, the adjusted gross outcome with retreatment once a year of Kenya 1 could contribute to an over-optimistic ratio, because the effects of ITN with reduced frequency of treatment should reduced accordingly; yet it was not taken into account of the adjusted ratios. From the recalculation in Appendix 1, which remains the retreatment yearly and uses data from the original study, the cost per DA was 2000US\$ 2440. Thus the cost per DA with annual retreatment could be somewhere between 2000US\$ 2019-2440.

For children less than 5, the cost per DA and DALY were given of 2000US\$ 1559 and US\$ 57 respectively in Tanzania study. The adjusted comparable result of Kenya 1 is recalculated as 1996US\$ 61 of cost per sick child averted (Appendix 2). Tanzania estimated another 42 deaths averted in 1-4 age group. The results from the two studies with regard to malaria prevention in childhood are not being able to compare directly.

There were three one-way sensitivity analyses provided by Tanzania study. It included scenarios of effects conferred by untreated nets; level of coverage achieved by the end of the project and duration of the effect of insecticide treatment. The best scenario was estimated as 50% treated nets coverage with 19% untreated net, then, the cost per DA would be 2000US\$ 587 and cost per DALY US\$ 22. Kenya 2 conducted one-way sensitivity analyses on changing conditions of discount rate, frequency of net

treatment, cost of insecticide, unwaged labour, wages of programme staff and funeral costs. The best scenario would be a 20% lower cost of insecticide combined with yearly retreatment, when the cost per DA would be 1996US\$ 839 (with community effect).

The social marketing approach of ITN programme had disappointing net coverage and retreatment rates (Cham et al 1997, Chavasse et al 1999). In Tanzania study, it was estimated that net coverage was low at 14% in Ulanga and 23% in Kilombero after less than two years implementation. The retreatment rate calculated in Appendix 4 was disappointing at 6.3% (It's calculated Appendix 4). It could expect lower effectiveness of the programme associated with the very low retreatment rate. The costs of social marketing approach of ITN programme is expecting higher than public delivery system. Tanzania used cheaper and longer lasting insecticide of pyrethroid than Kenya 1 (permethrin). However, the biggest single item of costs contributed in Tanzania was personnel, which offsets savings from insecticide compared with Kenya 1. With the price of nets similar, the average personnel cost of Tanzania was twice that of Kenya 1. The lower effectiveness associated with low retreatment rate and the high costs of implementing the programme could explain why the Tanzanian study was much less cost effective than Kenya 1.

With similar assumptions made of 5 years useful life of net, retreatment once a year and a 3% discount rate for capital goods (assuming similar characteristics of malaria transmission), the two studies were highly comparable in terms of the cost-effectiveness of different delivery mechanism.

Kenya 1 also explored the mass effects of ITN by assuming that ITN effects extended to proximity within 300 meters of non-ITN users. The gross 1-11 months infants DA was at 1996US\$ 2039 (Appendix 1) with retreatment twice a year. There were 12 more infant's death averted with the setting. However, there was no evidence to back the assumption. Also it is important to note that the magnitude of the community health effects will be influenced by population density in areas neighbouring intervention zones.

The other two CEAs simultaneously were aimed to compare the cost-effectiveness of ITNs with RHS. The South African study was from a trial condition, whilst Kenya 2 from a programme condition. Both studies were conducted in the area that has similar malaria transmission characteristics: low intense, seasonal endemic transmission. Kenya 2 assumed 2 people a net and used insecticide of deltamethrin. The study estimated a 63% adjusted incidence rate, which was less effective than RHS (75%), and a gross cost per case prevented at 2000 US\$ 29. As for the delivery mechanism, Kenya 2 used socio-marketing approach with expatriate personnel participation which contributed high personnel cost - 62% of total costs. The study provided two scenarios of sensitivity analysis – number of nets sold per community and the price of insecticide. It was estimated that with at least 1025 nets sold per community group (base study was 400), ITNs could compete with two cycles of RHS.

The South African study was not readily comparable with other cost-effectiveness ratios which compared with a no intervention situation. The result setting of the study was incremental cost-effectiveness ratios compared with RHS. The trial provided a treated net to average 1.7 people, with sachets of the synthetic pyrethroid permethrin at a target dose of 200mg/m<sup>2</sup>. The net retreated annually without wishing before the retreatment. The study showed 69% adjusted incidence rate of ITN over RHS. In the base case, the incremental economic cost per person of ITNs compared RHS of 2000US\$1.42/R8.68 (1999 price) per year; gross incremental cost per case averted of US\$ 18/R111; gross incremental cost per death averted of US\$1915/R11718. In the sensitivity analysis, it showed that including drug cost savings, it would be net savings from using ITNs compared with RHS with a useful life of more than 8.8 years, which in the base case the useful life was 4 years, or at a net price under US\$ 3.57/R21.85, where in the base case the net was priced at US\$12.09/R74.

If the discount rate adjusted to 3%, the incremental cost per case averted of South African study would be at US\$ 16.5 (from sensitivity analysis). If the useful life year of nets adjusted from 4 years to 5 years, the ratio would even lower. Comparing with Kenya 2, the cost per case averted at 2000US\$29, with the knowledge from the study that RHS cost per case averted at US\$ 9, the ratio from South Africa study was much lower than Kenya 2 (with a net useful life of 6 years and a discount rate of 5.3%, the South Africa ratio was US\$ 8.3 per case averted). In South African study, it provided

3206 nets (5450 people with average 1.7 people a net) with 855 incremental case averted by ITN compared with RHS, whilst Kenya study estimated 13 case averted by providing 274 net, that is, 3.7 nets provided one incremental case averted in South Africa study and 21 nets provided case averted in Kenya 2 study. The effectiveness of ITN was astonishingly different of the two studies that conducted in the areas of similar malaria transmission condition. It is hard to explain such a disparity.

The major cost of South Africa study was nets and initial insecticide, which account for 54% of total costs; this might due to the high price of nets – the price of US\$ 12.09 per net was 2.7 times as high as the price in Kenya 2 study. In contrary, the major cost of Kenya 2 study was organised community groups, which constituted 62% of total cost; this might due to the high salary of expatriate personnel. It signifies ITN would be a more attractive cost-effective health investment of scarce resource use for malaria control, if the price of ITNs in South African study could be decreased to half, and the expatriate personnel in the Kenya 2 study could be reduced sharply.

Concerning the comparison of ITN and RHS, the results of the two studies were quite different. In the South Africa study, ITN was more effective than RHS with an adjusted incidence rate of 69% compared with RHS, whilst in Kenya 2 study, RHS reduced infection risk by 75% compared with ITN 63%. It is hard to explain why the effectiveness of ITN in South African study was much higher than that in Kenya 2 study.

CEAs of ITN covered in current study all included provision and treatment of nets. For infants, cost per death averted ranged from 1996US\$ 2019 (Kenya 1) to 2000US\$ 2879 (Tanzania); for children, cost per death averted was 2000US\$ 1559 (Tanzania) and cost per sick child averted was 1996US\$ 61 (Kenya 1) (Appendix 2); and with no specific age-group concerned, cost per infection case prevented was 2000US\$ 29 (Kenya 2). There were 6 CEAs of ITNs covered in a CEA review of malaria interventions (Goodman et al, 1999a). For insecticide treatment only to existing bednets, cost per child DA ranged from (1995) US\$ 219-\$829, and cost per DYLG ranged from \$9 -\$27; for provision and insecticide treatment, cost per child DA ranged from \$2112-\$2958, and cost per DYLG ranged from \$10-\$118.

Of the four CEAs, only the South African study mentioned compliance rate of using ITNs. People provided with ITNs may still sleep outside them due to hot weather, or nets provided to children maybe used by adult males (Binka et al, 1997). This may reduce the effectiveness of ITNs and alter the CEA ratio. The compliance rate may increase by information and education provided. Retreatment rate in South Africa study was 100% and Tanzania 6.3% (Appendix 4). In other operational African settings, they have often been under 25%, especially where there are some charges for service (Chavasse et al., 1999).

There are some new features of the CEAs covered in the current study. First, two CEAs were from programme settings. Comparing with trials, programmes involve routine delivery services. There is less control over the process and reflect the real compliance rate, retreatment rate and washing frequency of using nets. Secondly, those two programme setting CEAs also explored cost-effectiveness in different delivery mechanism of ITN operation. The delivery mechanisms of those two were socio-marketing approach with no free charge to nets and insecticide. To scale-up ITN programme, the socio-marketing approach is advocated as a very important method to compensate public health approach. However, the two studies didn't explicitly explore the coverage rate, compliance rate and retreatment rate of ITNs. Thirdly, the Kenya 1 study also explored mass effect of using ITNs, which the subject had mentioned but never quantified before. In estimates cost savings, Kenya 1 included funeral costs, which is rational and made the ratio more cost-effective. Moreover, South African study gave incremental ratios with RHS, which could provide decision-makers with a clearer picture of the two interventions.

Interestingly, the four CEAs of ITNs could view as two pairs of study. One pair was from intense and perennial malaria transmission, the other from low intensity, seasonal and epidemic-prone malaria transmission. Both pairs had two different settings of programme and trial condition, enabling comparison of results from two different settings directly.

The public delivery method could be described as a government programme established to purchase insecticide and organize net retreatment, and where necessary distribute nets, with no charges for users who provided only limited amounts of labour and resources such as water and detergent. The social marketing approach of the ITN programme could be a partnership between commercial organization or non-governmental organisation, local community, and government, normally with charges for nets and retreatment services and gaining subsidies from government.

With regard to ITNs social marketing approach for malaria control, several issues may need some attention. Firstly, the social marketing approach normally has disappointing net coverage rate and retreatment rate (Cham et al.1997, Chavasse et al. 1999). The affordability of nets and insecticide has great influence on the coverage rate and the retreatment rate of the ITNs. In turn, the effectiveness of ITN will be great influenced. Secondly, the cost structure had been showed very different with public health mechanism. The cost of expatriate personnel normally contributes the biggest proportion of the total costs (Tanzania and Kenya 2), and the much higher total costs than public delivery approach contributes to higher CEA ratios. The cost-effectiveness of ITN social marketing approach could be great improved with lowered price of nets and insecticide, and much reduced expatriate personnel. In the Kenya 2 study, the assumption of reducing 50% expatriate personnel could reduce 17% total cost, which is very impressive.

Further, the sustainability of nets and insecticides supply, which need to be supported by the sustained funds, may also be noticed. The sudden drop of a malaria prevention programme might lead to serious malaria explosion. With acceptable cost-effectiveness, the disappointing net coverage and retreatment rate may indicate that the social-marketing approach of ITN programme could be used in endemic area, which allows slow improvement in malaria control. However, concerning epidemic-prone areas or the areas have important role as a barrier of spreading malaria to other areas like northern KwaZulu-Natal in South Africa, where tight control is needed to prevent explosive transmission, the social marketing approach is not ideal.

### 4.3 Residual spraying

Residual house spraying involves the treating of all interior walls and ceilings with an insecticide, and is effective against mosquitoes that favour indoor resting before or after feeding. In the 1940s-60s, spraying the inside surfaces of houses with a residual insecticide, principally dichlorophenyltrichloroethane (DDT), was the main means by which the incidence of malaria was reduced to zero, or near zero, in regions where malaria was endemic (Curtis and Lines, 2000). The epidemiological concept of the interruption of malaria transmission by residual insecticide spraying is simple. After taking her blood-meal the female anopheles usually rests on a nearby indoor surface such as a wall, ceiling, etc. for several hours while the blood-meal is digested and the batch of eggs matures. Spraying of all inside surfaces of dwellings with a long-lasting insecticide means that a substantial proportion of anopheles would be killed before they could transmit the disease. However, mainly because of the declining ability or willingness of governments or donors to continue funding the spraying programmes on a sufficient scale, there has been a resurgence of malaria, though so far not to the levels of the 1930s (Curtis and Mnzava, 2000). Now residual house spraying remains a major component of control programmes in southern African states (WHO, 1994), though many countries have abandoned or curtailed their spraying activities due to concerns over the safety of DDT and environmental impact, and political and economic pressures from international environmental agencies and donors.

It appeared that the widespread use of DDT and other residual insecticides for residual house spraying was the most reliable, feasible and economical method for the interrupting of transmission. It was estimated that fenitrothion residual house spraying brought down the daily parasitological inoculation rate by 96% from the antimalaria programmes in a large scale field trial near Kisumu, Kenya from 1972-1976 (Payne et al 1976, Fontaine et al 1978). The effectiveness of residual house spraying with DDT, pyrethroids, and malathion had been also proved by many other studies (Kouznetsov 1977, Dradley 1991, Delfini 1969, Molineaux 1980, Rowland et al 1997). However, when recent outcomes from residual house spraying are compared with spraying projects from the 1950s-70s, against apparently similar vector populations, the recent results appear to be inferior (Curtis and Mnzava, 2000).

The cost-effectiveness analysis for residual house spraying is even sparser than that of ITNs, partly because the use of residual pyrethroids to treat bednets has become more fashionable than house spraying.

Kenya 2 and South Africa compared CEAs of ITN and RHS for malaria control. Kenya 2 gave gross CEAs of RHS. The study was a programme setting in an epidemic-prone, low intense transmission area in Western Kenya, and used lambdacyhalothrin as insecticide, which reflected the recent trends of advocating other insecticide than DDT. The programme of RHS reduced infection risk by 75%, while ITN was estimated as 63%, and the cost per person protected was 2000US\$ 0.88 and cost per per infection case prevented 2000US\$ 9. The major cost components were 76.3% insecticide, 20.4% project and 1.6% training.

The South African study didn't give CEAs of RHS. The RHS study in South Africa was only as a base of calculating incremental costs of ITNs. The study was from northern Kwazulu Natal, South Africa, with similar malaria transmission properties as Kenya 2. The RHS programme had changed insecticide from DDT to permethrin and pyrethroids since 1996 (Goodman et al, 2000). In the study, the ITN adjusted incidence rate compared with RHS was 69%; the incremental cost per case averted was 2000US\$ 18, and incremental cost per death averted was 2000US\$ 1915. The authors concluded that even through economic costs are higher, ITN was a cost-effective use of resources.

The really high adjusted incidence rate of ITN over RHS of 69% indicated some other issues. If we assume the adjusted incidence rate of using ITN compared with no protection was 75%, then the adjusted incidence rate of RHS would be 44%. Notice that in South Africa, the insecticide for residual house spraying has changed as mentioned above. Does it mean that permethrin and pyrethoid for residual house spraying has much lower effectiveness than DDT, because after fighting with DDT for long period of time, mosquitoes might become resistant? If it is the case, decision-makers should pay attention to it because the study area has an important role as a barrier area against the spread of malaria to the south.

However, a likely explanation of this puzzle appeared from another study. Hargreaves et al (2000) pointed out that the failure of pyrethroid spraying in preventing a rise in malaria cases was attributed to *An. funestus*, which apparently had been eradicated by DDT in the 1950s, but has re-emerged and now shows pyrethroid resistance. This pyrethroid resistance has prompted a return to spraying with DDT.

There were two CEAs of RHS in Goodman and Mills' review (1999a). The Garke, Nigeria (Molineaux et al, 1980) one was conducted from a trial. The cost per case prevented was US\$ 342. The result was much higher than the current one of Kenya 2, and as Goodman et al pointed out, 'this result (Barlow and Grobar, 1986) is difficult to interpret because the costs covered both research and implementation activities, and appear to have included some costs of the accompanying drug administration and larviciding...'. The other, Walsh and Warren (1979) used a simple model to calculate average estimates for a rural area of SSA with twice yearly DDT spraying. The study assumed reductions in the crude death rate of 40% and the infant mortality rate of 50% based on trials in the 1950s and 1960s, and derived a cost per adult DA was US\$584, and cost per infant DA was US\$ 1402. Goodman et al (1999a) questioned these results because the cost dates of the study were based on a WHO report (1974) and covered adult mosquito and larval control in a 'small area of economic importance', so it was not possible to isolate the costs of spraying alone. The study area – an agricultural development project – was not a typical sub-Saharan rural area.

#### **4.4 Chemoprophylaxis For Infants**

Chemoprophylaxis for malaria control normally is advocated for malaria vulnerable groups, such as non-immune travellers, pregnant women and children under 5 years of age. Till 1998, the strategy was not implemented for children in SSA, although large-scale programmes had been undertaken in several countries in the past, such as Senegal, Ghana, Niger, and Burkina Faso (Goodman, 1999a).

The effectiveness of chemoprophylaxis has been reviewed by Geerlings et al (2003). The study observed significant reductions in parasitaemia in children who received chemoprophylaxis, which varied from 10.9% to 100%, in 42 studies. They also

identified nine articles that reported information on child mortality. They observed substantial evidence of mortality reduction in children who receive prophylaxis with pyrimethamine-dapsone over 2-5 years from studies in Gambia, and no significant effects on mortality reduction from other studies that used shorter periods of chemoprophylaxis and included small numbers of participants.

Gonzalez et al (2000) analysed cost-effectiveness of two malaria chemoprophylaxis control strategies for infants (under 1 year age)(chemoprophylaxis + iron, and chemoprophylaxis) hypothetically delivered through the Expanded Programme on Immunization (EPI) based on the study of Menendez et al (1997). The study conducted in an area of intense perennial malaria transmission. Weekly malaria chemoprophylaxis with a combination of 3.125 mg pyrimethamine and 25 g dapsone per % ml (Deltaprim) were administered at home by village health workers to infants from 2 months to 12 months of age at a dosage of 2.5 ml per week. Daily iron supplementation were administered by mothers to infants from 2 months to 6 months of age. The two control strategies were chemoprophylaxis alone or combination of the two. The effectiveness of first episodes of clinical malaria of the two strategies were 65.9% and 59.4% respectively for chemoprophylaxis + iron and chemoprophylaxis alone. From the perspective of the health provider, the cost-effectiveness ratios were, respectively, 1996US\$ 9.7 and US\$ 10.2 per disability-adjusted life year (DALY) for malaria chemoprophylaxis with Deltaprim (a combination of 3.125 mg pyrimethamine and 25 mg dapsone) + iron and Deltaprim alone. From a sociocultural perspective the cost-effectiveness ratios ranged from US\$ 11 to US\$ 12. It also gave cost per child protected for health care provider of US\$ 7.3 and US\$ 7.0 for Deltaprim + iron and Deltaprim alone respectively, compared with standard case management of US\$10.4. The general conclusion of the study was that the strategies were highly cost-effective and less costly than the clinical case management.

The framework of calculating CE ratios of the study was different with those of other malaria studies in Africa. The results in the view of health provider included intervention costs and costs of clinical case management to the intervention-implemented groups who were not protected from the interventions. The results of the study were not readily comparable with the other malaria chemoprophylaxis control settings and malaria prevention settings in Africa. To provide comparable gross ratios,

the current study uses the initial data of interventions costs and effects estimates, and recalculates the ratios. Details are in Appendix 5. The gross cost per DALY of chemoprophylaxis plus iron was 1996US\$ 5.0, gross cost per DALY of chemoprophylaxis was 1996US\$ 4.1. From costs data of the study (Gonzalez et al, 2000, p101), the costs of clinical malaria treatment was similar with the intervention costs of chemoprophylaxis plus iron, and much higher than the intervention costs of chemoprophylaxis. It indicated that net cost-effectiveness ratios, which include malaria treatment savings and savings from households, would be negative, in other words, the intervention was a net saving for both health providers and households, which was consistent with the conclusion of the study.

In other studies, malaria chemoprophylaxis alone was estimated to cost US\$ 143 (1990 prices) per death averted in Gambia (Picard et al, 1992), and cost US\$2.8 per child protected per season, compared with the current one of US\$ 2.7 at 1996 prices. Generally, chemoprophylaxis appeared to be more cost-effective than standard case management/ or net treatment in the both chemoprophylaxis studies conducted in Tanzania and Gambia. However, compliance might need more investment as mentioned in Picard et al (1992) study, average compliance was 60% and dropped to 33.6% in the longer period.

#### **4.5 Environmental management for malaria control**

Environmental management for malaria vector control was first used in Selangor, Malaysia, where vegetation clearance and drainage and filling of aquatic habitats in forested wet-lands and in towns were used to control one of the local lowland malaria vectors (Sandosham, 1959). Currently, there is a renewed interest in environmental management (EM) among vector control specialists, partly in response to a series of problems faced by many vector control programme; increased costs of insecticide production, marketing, and distribution; stricter toxicologic testing; vector resistance to certain insecticides; and limited field success with biological control measures (Lacey and Lacey, 1990). Solutions are being sought not solely through traditional eradication programmes, but through the use of EM, a deep understanding of vector

ecology, and the integration of the various control strategies (chemical, biological, genetic, EM, etc.) (Ault, 1994).

Scientific knowledge of the often adverse ecological and public health effects of large dams, other development projects and vector control strategies has grown, beginning in the 1950s, but most noticeably since the 1970s (Farvar et al. 1972, Stanley et al. 1975, Scott et al 1982, Service et al. 1989). In parallel, there arose a wider application of ecologic principles in insect pest and vector management. EM can provide cost-effective means to suppress, diverse and exclude vectors associated with rural development and urbanisation, and public health improvement in the tropics. It often promotes the use of health and sanitation education of appropriate technologies, clean-up campaign, and community participation with an emphasis on self-help strategies for vector control (Ault, 1994).

One cost-effectiveness analysis of environmental management for malaria control is found from re-analysing programmes conducted between 1929-1949 by Utzinger et al (1999). They undertook a cost-effectiveness analysis of EM for malaria control from a large-scale, multifaceted malaria control programme that incorporated environmental management as the central feature. The programme was launched in 1929 and implemented for 2 decades at copper mining communities in Zambia before dichlorodiphenyltrichloroethane (DDT) was widely used. The full package of control measures, which was targeted mainly at source reduction of larval habitats of the predominant malaria vector, consisted of vegetation clearance, modification of river boundaries, draining swamps, oil application to open water bodies and house screening. Part of the population also benefited from quinine administration and was sleeping under mosquito nets. Within 3-5 years, malaria-related mortality, morbidity and incidence rates were reduced by 70-95%. Over the entire 20 years of implementation, the programme had averted an estimated 4173 deaths and 161205 malaria attacks. The estimated costs per death and malaria attack averted were US\$ 858 and US\$ 22.20 respectively. Over the initial 3-5 years start-up period, the costs per disability adjusted life year (DALY) averted were US\$ 524-591, and in the longer term, as the maintenance costs were much lower, US\$22-92 per DALY averted.

The programme was highly successful. With fewer adverse ecological effects, sharp declines in malaria-related outcome measures were observed shortly after the programme was initiated, and after 3-5 years the package exhibited a high level of performance. With effectiveness of quinine administration, sleeping under mosquito net and last 5 years DDT spraying, the cost-effectiveness ratios, which the costs only included recruitment of 300 men for vegetation clearance, modification of river boundaries and drainage of swamps, and the annual maintenance of these interventions, seem to be underestimated. Moreover, the study excluded costs of supervision of mine management and entomological surveys which formed the knowledge base for tailoring environmental management strategies. The ratios are therefore bottom lines of cost-effectiveness of EM intervention. Comparison of these ratios with other CEAs is difficult.

**Table 4.2 Base-case settings and assumptions**

Studies	ITN-Tanzania	ITN- Kenya 1	ITN- Kenya 2	ITN- South Africa	RHS	Chemoprophylaxis (based on Menendez C et al 1997)	Environmental management (EM)
<b>Author/year</b>	Hanson et al., 2003	Wiseman et al., 2003	Guyatt et al., 2002	Goodman et al., 2001	Guyatt et al., 2002	Gonzalez et al, 2000	Utzinger et al, 2001
<b>Place/year</b>	Southern Tanzania, Jul 1996-Jun 2000	Western Kenya, Jan 1997 – Mar 1999	Western Kenya, 2000	Northern Kwazulu Natal, South Africa, 1998-1999	Western Kenya, 2000	Kilombero District, Tanzania, 1996	Copper mines in Zambia, 1929-1949
<b>Price in US\$ year</b>	2000 US\$ (Tsh 803/US\$)	1996 US\$	2000 US\$	2000 US\$ (R6.12/US\$)	2000	1996	1995
<b>Setting</b>	Programme	Group-randomised controlled trial	Programme	Trial	Programme	Randomised controlled trial	Large-scale, multi- faceted programme, with centre feature of EM
<b>Malaria transmission</b>	Intense and perennial	Intense and perennial	Epidemic-prone, low intensity, stable	Seasonal endemic but low intensity	Epidemic-prone area, low intensity, stable transmission	Intense perennial malaria transmission	Hyperendemic malaria transmission
<b>Delivery mechanism</b>	Social marketing with expatriate personnel; users share costs	Research program and community partnership; free in charge of nets and insecticide	Social marketing with expatriate personnel; users share costs	Using existing health control teams, free in charge of nets and insecticide	4 mobile teams (Merlin and health staff), free to charge	Expanded programme on Immunization (EPI)	Organised by mining management, with a team of 300 men
<b>Target group</b>	Children less than 5 and infants	Children less than 5 and Infants				Infants	
<b>Design</b>	-I: Deltamethrin, lambdacyhalothrin -ID: 20mg/m2 -P: Nets: US\$4.7 (sold 65111) Insecticide kit: US\$ 0.42 (sold	-I: Permethrin - ID: 0.5g of permethrin /m2 of netting - P: Duty free price of insecticide Nets: US\$ 5*	-I: K-othrine 1% SC (deltamethrin) - P: 285 sold at US\$ 0.64, the rest at US\$ 4.47 - NUL: 5 years - NC: Assuming 2	-I: Deltamathrin (98) /permethrin (99) - ID: 200mg/m2 - P: Nets R74/ US\$ 12.09 Deltamethrin: R	-I: Icon 10% WP (lambda- cyhalothrin, 100 g/kg ai) -Round: 1/year	1) Daily iron supp. administrated by mothers 2) Weekly chemoprophylaxis administrated at home by village	-Detailed entomologic surveys for tailoring the strategy -Targeting the larval stage: vegetation clearance,

	24393) -NUL: 5 years - NC: 14% Ulanga, 23% kilombero - RF: 1/year - **RR: 6.3%	(45667 nets) - NUL: 5 years - NC: 1.34 people per ITN - RF: 2/year	people a ITN - RF: 1/year	5.91/ US\$ 0.96 Permethrin: R10.96/ US\$ 1.79 - NUL: 4 years - NC: 1.7 people per ITN - RF: 1/year - RR: 100%		health workers -Design 1: 1) + 2) -Design 2: 2)	modification of river boundaries, draining swamps, oil application to open water bodies and house screening -With part of quinine administration and sleeping under nets
<b>Discount rate</b>	3%	3%	3%	5.3%	3%	3%	3%
<b>Life expectancy</b>	54.2 years at birth, 58.6 years at the age of 3 years	Average 48.5 years at six months of age		Data not available			At births of 50 years
<b>Major economic cost component</b>	***Personnel: 27.7%, nets and packaging: 25.4%, insecticide: 5.5 % (30% financial cost borne by users)	ITNs: 40% Staff: 21% Insecticide: 9%	Organised community groups: 62% Nets: 19% Insecticide: 19% (cost per net recovered by users was US\$ 3.20)	Nets & initial insecticide: 54% *DoH personnel: 21% Insecticide and retreatment: 15%	Insecticide: 76.3% Project: 20.4% Training: 1.6%		
<b>Compliance</b>				98%			

\*I: insecticide, ID: insecticide dosage, P: price, NUL: net useful life, NC: net coverage, RF: retreatment frequency, RR: retreatment rate, DoH: department of health.

\*\* Retreatment rate calculation is in Appendix 4

\*\*\*It's calculated from Tanzania study's table 3 – annual economic cost (2000 prices) of KINET

**Table 4.3 Gross cost-effectiveness results for interventions using comparable outcome measures**

Reference	Area studies and study year	Intervention evaluated	Effectiveness	Outcomes	Sensitivity analysis available
<b>Prevention in infants</b>					
Hanson et al. 2003 (ITN-Tanzania)	Southern Tanzania, Jul. 1996-Jun. 2000	ITNs (social marketing approach)	27% protective efficacy	Death averted: 52 ***Cost per DA: 2879 ***Cost per DALY: 111 (US\$ in 2000 price)	-Effects conferred by untreated nets -Level of coverage achieved by the end of the project -Duration of the effect of insecticide treatment
Wiseman et al. 2003 (ITN-Kenya 1)	Western Kenya, Jan. 1997- Mar. 1999	ITNs (trial)	23% protective efficacy 27% reduction in the number of sick child	Death averted: 61 **Cost per DA: 2019 (US\$ in 1996)	-Discount rate: 6%, 10% -Frequency of net impregnation: once a year -Cost of insecticide: 20% increase/decrease -Unwaged labor: 25% above/below -Wages of programme staff: 50% reduction -Funeral costs: 50% reduction
Gonzalez et al. 2000 (date based on Menendez et al. 1997) (Chemoprophylaxis)	Tanzania, 1996	Chemoprophylaxis hypothetically delivered through EPI	Effectiveness of *FECM: *C+I: 65.9% *C: 59.4%	****C+I, cost per DALY: 5.0 ****C, cost per DALY: 4.1	-Low effectiveness estimate at C+I 39.7% and C 32.9%: health provider perspective, DALY of C+I: US\$ 21.9, DALY of C: US\$ 25.8; sociocultural perspective, DALY of C+I: US\$ 26.2, DALY of C: US\$ 31.5 -Varying percentages of episodes treated through the health care system -Two-way sensitivity analysis, comparing the cost-effectiveness of C+I with standard case management
<b>Prevention in childhood</b>					
Hanson et al. 2003 (ITN-Tanzania)	Southern Tanzania, Jul. 1996-Jun. 2000	ITNs (social marketing approach)	27% protective efficacy	Death averted: 97 Cost per DA: 1559 DALY: 57	-Effects conferred by untreated nets -Level of coverage achieved by the end of the project

					-Duration of the effect of insecticide treatment
Wiseman et al. 2003 (ITN-Kenya 1)	Western Kenya, Jan. 1997- Mar. 1999	ITNs (trial)	23% protective efficacy 27% reduction in the number of sick child	**Cost per sick child averted: 61 (US\$ in 1996)	-Discount rate: 6%, 10% -Frequency of net impregnation: once a year -Cost of insecticide: 20% increase/decrease -Unwaged labor: 25% above/below -Wages of programme staff: 50% reduction -Funeral costs: 50% reduction
<b>Prevention with no specific age-group</b>					
Guyatt et al, 2002 (ITN-Kenya 2 and RHS)	Western Kenya, 2000	ITN (social marketing approach) RHS	ITN: 63% adjusted incidence rate RHS: 75%	ITN: Case averted: 13 cases/ 274 nets Cost per infection case averted: 29 RHS: cost per infection averted: 9 (US\$ in 2000 price)	-Number of nets sold per community group -Price of insecticide
Jurg Utzinger et al, 2001 (EM)	Zambia, 1929- 1949	Environmental management	In 3-5 years: incidence rate reduced 70-95%	Averted 4173 deaths and 161205 malaria attack DA: 858 Cost per malaria attack averted: 22 DALY: 22-92 (US\$ in 1995 price)	

\*FECM: first episodes of clinical malaria; C+I: chemoprophylaxis +iron; C: chemoprophylaxis; CCP: cost per child protected.

\*\* Recalculated from original data, details are in Appendix 2

\*\*\* Recalculated from original date, details are in Appendix 3

\*\*\*\* Recalculated from original date, details are in Appendix 5

## **CHAPTER 5    CEA STUDIES OF MALARIA PREVENTION AND MALARIA CONTROL**

### **5.1 CEA of Malaria Prevention**

#### **5.1.1 Results and their comparability**

Cost-effectiveness analyses of malaria prevention covered in this study include interventions of ITNs, RHS, chemoprophylaxis for infants, and environmental management. The most effective way of malaria prevention was environmental management with an adjusted incidence rate of 78% (70-95%). For infants, ITNs provided cost per death averted ranged from US\$ 2019 (Kenya 1) – US\$2879 (Tanzania) and cost per DALY US\$ 111 (Tanzania); chemoprophylaxis provided cost per DALY US\$ 4.1 (Gonzalez et al, 2000) and cost per DALY of chemoprophylaxis plus iron US\$ 5.0. For children, ITNs gave a cost per DA US\$ 1559 (Tanzania), cost per DALY US\$ 57 (Tanzania) and cost per sick child averted US\$ 61 (Kenya 1). For non-specific age-group, EM gave cost per DA US\$ 858 and DALY US\$ 57; ITNs gave cost per infection averted US\$ 29, and RHS US\$ 9. According to the guideline that any intervention with a cost per DALY below US\$ 150 is an attractive use of resources, in a low-income country (WHO, 1996), ITN, chemoprophylaxis and EM can be considered as cost-effective means of preventing malaria. Meanwhile, with the knowledge of lower ratios of RHS than ITN (Kenya 2), RHS could also be included.

To meaningful compare CEA results, the studies must have included a comparable range of costs and effects and followed a similar methodology, for example to value community time, and discount costs and effects. In addition, it's better to have measures of effectiveness that is common across the interventions being compared (Goodman et al, 1999a). In the study, the results settings and effectiveness measures of these studies are impossible to adjust and remain the same. When these results are compared, there is a need to identify the age groups that results were taken from, and bear in mind the different effectiveness measures. However, the author has adjusted the settings and assumptions of these studies more comparable. The South African study remained non-comparable with the others because it gave incremental ratios with RHS.

Also, it is important to notice that studies from trials, which may be unrepresentative of routine service delivery, may have over-optimistic estimate of effectiveness and cost-effectiveness. Therefore costs are adjusted to remove any research-related expenses and compliance is likely to be much higher than operational settings. The study of environmental management excluded costs of entomological surveys, management supervision, nets provision, quinine treatment and DDT intervention during the last 5 years of the programme, so the cost-effectiveness ratio may appear more attractive than reality. Further, the adjusted ratios, such as retreatment frequency of ITN from biannually to annually, which may affect the effectiveness accordingly, may lead to over-optimistic outcomes.

In addition, cost-effectiveness ratios are influenced by various factors specific to each intervention. These factors cannot be altered easily especially the geographic settings, like epidemiological conditions and demographic factors, so that, one-way or even multi-ways adjustments of settings may still provide distorted ratios. These include, according to (Goodman et al, 1999a; Goodman et al, 1999b):

- ❖ The length of the transmission season, which may influence the retreatment frequency of ITN and the rounds per year needed of RHS;
- ❖ The intensity of malaria transmission, which through effects could influence the ratios;
- ❖ The population density, which may influence the mass effect of ITN, and the effectiveness of RHS;
- ❖ The scale of intervention, which may influence the costs especially using social-marketing approach for ITN;
- ❖ The price of inputs, such as nets, insecticides and salaries;
- ❖ The delivery system – public system or social marketing approach – which could influence both costs and effects;
- ❖ Behavioural factors, such as compliance with chemoprophylaxis regimens and usage and retreatment rates for nets;
- ❖ The degree of existing infrastructure, and
- ❖ The degree of drug and insecticides resistance.

Moreover, immunity levels, the acceptability of the intervention to local people and the availability of managerial capacity, all contribute differences in cost-effectiveness ratios. Along with the progress of the techniques of cost-effectiveness analysis, researchers tend to customise their study designs specific towards their interests and local conditions, like the chemoprophylaxis study in Tanzania, the South African study, and Kenya 1. The fact made inter-study comparison of cost-effectiveness concerning malaria prevention more difficult.

### **5.1.2 CEAs of malaria prevention in sub-Sahara Africa before 1998**

Goodman and Mills (1999a) reviewed 11 CEAs of malaria prevention available up to the end of 1998 that used African data. The review covered malaria prevention interventions of insecticide-treated nets, residual spraying, chemoprophylaxis and hypothetical vaccine for children, chemoprophylaxis or intermittent treatment for pregnant women. For ITNs, cost per DA ranged from 1995 US\$ 219-2958, cost per DYLG ranged from \$9-118; for hypothetical vaccine, cost per DA was \$296, cost per DYLG ranged from \$0.36-\$621; chemoprophylaxis for children, cost per DA was \$167; and chemoprophylaxis for pregnant women, cost per child DA ranged from \$81 – 950. In addition, Goodman, Coleman and Mills (1999b) used a modelling approach based on probability sensitivity analysis and obtained data from published and unpublished sources and consultations with researchers and programme managers to calculate ranges for the cost per disability adjusted life year (DALY) averted. They found that in a very-low-income country, for insecticide treatment of existing nets, the cost-effectiveness range was U.S. \$4-10 per DALY averted; for provision of nets and insecticide treatment, \$19-85; for residual spraying (two rounds a year), \$32-58; for chemoprophylaxis for children, \$3-12 (assuming an existing delivery system in place); for intermittent treatment of pregnant women \$4-29; and for improvement in case management, \$1-8.

The ranges of CE ratios from the current review, the review from Goodman et al (1999a) and the modelling study from Goodman et al (1999b) for ITN, RHS, chemoprophylaxis and EM are summarised in Table 5.1. The whole ranges of CE ratios for ITN, RHS, chemoprophylaxis and EM that combined the three studies are displayed in Table 5.2, regardless of age group. While a strict comparison of CEAs of

malaria prevention from various settings is impossible, the table presents a general sense of cheapest among these cost-effective malaria prevention methods. In general, chemoprophylaxis appears to be the cheapest solution for malaria prevention, followed by RHS 1 round a year, RHS 2 rounds a year, ITN with existing nets and ITN with net provision and treatment. The EM ratios provided by Utizinger et al (2001) were little higher than ITN with net treatment only. However, it was impossible for the study to isolate costs and effects from other interventions, such as, nets, chloroquine administration and lost five years of DDT spraying. The ratios of EM could be expected to be much higher and may come in between ITN with existing nets and ITN with net provision and treatment.

Earlier malaria economic evaluations in world context can be found from Barlow and Grobar (1986) and Mills (1987). Several cost-effectiveness analyses of malaria control and eight cost-benefit analyses of malaria control were covered Barlow and Grobar (1986), which used worldwide data. Mills (1987) conducted cost-effectiveness analysis of malaria control in Nepal.

**Table 5.1 The ranges of cost-effectiveness ratios of malaria prevention covered by the current review, and earlier studies (\$US)**

	Current review		Review of Goodman et al, 1999a (US\$ in 1995 price)		Modelling study of Goodman et al, 1999b
	Cost per DA	Cost per DALY	Cost per DA	Cost per DLYG	Cost per DALY
<b>Prevention in infants</b>					
ITN with net treatment only					
ITN with net provision and treatment	2019-2879	111			
Chemoprophylaxis with existing delivery system		4.1			
<b>Prevention in childhood</b>					
ITN with net treatment only			219-829	9-27	
ITN with net provision and treatment	1557	57	2112-2958	77-118	
Chemoprophylaxis with existing delivery system			167		3-12
<b>Prevention in all-age</b>					
ITN with net treatment only					4-10
ITN with net provision and treatment					19-85
RHS 1 round annually					16-29
RHS 2 rounds annually					32-58
Environmental management	858	57			

**Table 5.2 The general range of cost-effectiveness ratios of main malaria prevention interventions (\$US)**

Interventions	Cost per death averted	Cost per DALY	Rank
ITN with net treatment	219-829	4-111	4
ITN with net provision and treatment	1559-2958	19-85	5
RHS 1 round annually		16-29	2
RHS 2 rounds annually		32-58	3
Chemophophylaxis with existing delivery system	167	3-12	1
Environmental management	858	22-92	4-5

### 5.1.3 Cost-effectiveness data and public health policy

National and international police-makers urgently need to know which strategies are best for malaria prevention. Economic evaluation methods, and in particular cost-effectiveness analysis, can provide important information for identifying the interventions that present the best value for money. However, CEA of malaria control is sparse. No CEAs were found of untreated nets, other methods of personal protection (such as coils) and the control of epidemics. There is only one cost-effectiveness re-analysis found of environmental management for malaria control from a programme implemented during 1929-1949. For Africa, there are two CEAs of chemophylaxis for children, two for infants; two of hypothetical vaccine for children, and three of RHS.

More studies have been conducted since the review of Goodman et al (1999a). There are several studies filled the gap of CEA knowledge base of malaria prevention, such as a study of environmental management, ITNs studies with social-marketing approach and RHS with other insecticides than DDT. However, the studies from socio-marketing settings of ITN programmes didn't explore the net coverage rate, the compliance rate and retreatment rate. Moreover, while there are several successful instance of environmental management of malaria control, the CEA of EM are few. The current available CEA on EM is only one and with limited data of costs and effects, the study excluded costs of entomological surveys, management supervision, nets provision, quinine treatment and DDT intervention during the last 5 years of programme, and effects included all methods used, therefore, the cost-effectiveness

ratio may appear more attractive than reality. There is a critical need for more CEAs with quality costs and effects data.

Further, concerning the South African study, the effectiveness of ITN with deltamethrin and permethrin was much higher than RHS with lambda-cyhalothrin - the adjusted rate was 69% compared with RHS, which had opposite results with in similar malaria transmission area of Kenya (the study had 75% adjusted incidence rate of RHS with lambda-cyhalothrin and 63% adjusted incidence rate of ITN with deltamethrin) (Guyatt et al, 2002). The low effectiveness of the insecticide urges us to compare the effectiveness of RHS with DDT and other insecticides, especially where DDT was used before. As the South African study area plays a very important role of preventing malaria spread further down to southern, if the effectiveness of RHS with other insecticides drop sharply compare with the previous use of DDT, and RHS is still using as a major intervention of malaria prevention, then the potential danger of malaria spread to other areas will be high. Although WHO now recommends DDT spraying only in certain circumstances (e.g. for control of epidemics, areas of economic importance, refugee camps and initial protection of non-immune settlers in development areas), this should not prevent further scientific studies of DDT effectiveness analyses and cost-effectiveness analyses, especially where malaria prevention of RHS tend to switch or have switched from DDT to other insecticides.

The words from Goodman et al (1999a) are worth attention as regards methodology:

...only studies of ITNs provide a good basis for assessing allocative efficiency. Data to construct similarly comprehensive and methodologically sound estimates with ITN studies for other interventions are currently lacking and urgently required... More studies are evidently needed, but this takes time and it will never be possible to do studies on every possible situation... Also, in view of rapid growth in drug resistance ..., the likely development of pyrethroid insecticide resistance ..., and the possible reduction in the rate of immunity acquisition with effective protection ..., it is essential to consider potential changes in cost-effectiveness over time.

## **5.2 Malaria Prevention Interventions**

### **5.2.1 Malaria chemoprophylaxis**

From Table 5.2, which summarized results from the current CEA review, the review by Goodman et al. (1999a) and the modelling study by Goodman et al. (1999b), it is clear that malaria vaccine and chemoprophylaxis interventions in the sub-Saharan are among the most cost-effective of malaria prevention measures. However, malaria vaccine is still at the stage of laboratory development or small-scale experiment. And, wide-use of malaria chemoprophylaxis is not recommended, since it could substantially increase the growth of drug resistance, which would lower the cost-effectiveness of this intervention and possibly threaten the provision of effective case management. Chemoprophylaxis is promoted to be used by target groups, such as pregnant women and travellers. So, for large-scale malaria prevention, the choices are mainly left among ITNs, RNS and environmental management.

### **5.2.2 Insecticide treated nets**

The cost-effectiveness of ITNs programmes is sensitive to several factors. The first is the compliance rate of proper using ITNs. It is important to make sure that nets are used and especially used by malaria-vulnerable groups, even during seasons when their use is uncomfortably hot and there may not be enough biting by nuisance insects to make net use seem worthwhile. It is also important to make sure that people, especially children, go to bed before vectors start biting and do not get up before they stop. Nets must be kept in good repair, hung carefully, brought out for retreatment when required and not washed before retreatment. Second, considerable managerial skills are necessary for implementing ITN programmes. With limited implementation of ITN programmes in sub-Saharan Africa (Goodman et al, 1999a), the managerial skills required for effective operation are immense for most poor malarious countries, especially when the socio-marketing delivery approach is used. The scaling-up of the intervention might need quite a number of expatriate personnel, which could increase the costs sharply (Tanzania and Kenya 2). Third, ITN generally is the most expensive intervention among those cost-effective malaria control measures (Table 5.2). With

limited implementation of ITN programmes in sub-Saharan Africa (Goodman et al, 1999a), ITN programmes mainly need to provide and retreat nets, which is the most costly intervention among other cost-effective methods. Besides, every 4-5 years, nets need to be renewed. With the limited incomes of those poor malarious countries, the cost-effectiveness of the intervention will be reduced by low ITN coverage rate and retreatment rate, if charges are required. If financed by donors, the sustainability of funds should be assured – the sudden stop of malaria prevention could lead malaria infection exploded and wide spread.

Finally, ITNs may delay children's immunity, which could lead to the intervention no longer cost-effective. In 1999, Coleman et al, Guyatt et al and Kariuki et al pointed out that ITNs effective but may delay children's immunity. Research found that children sleeping under ITNs had markedly lower levels of anti-malaria antibodies than children not sleeping under bednets. Guyatt et al (1999) demonstrate that delayed immune acquisition is not a problem per se, but that the critical issue is whether it occurs immediately following the implementation of an ITN programme or whether it builds up slowly over time. In the 'worst scenario', where ITN immediately increase malaria mortality due to reduced immunity, the intervention might actually cost lives. In other words, it might be better to not use ITNs. On the other hand, if reduced immunity takes two years to develop, ITNs would still fall into the category of excellent value for money compared to other health interventions, saving a year of life at a cost of between US\$ 25-30. Coleman et al (1999) used model to present the cost and disability adjusted life year (DALYs) per child aged 1-119 months for a sub-Saharan population with and without ITNs. With mortality and morbidity reductions due to ITNs in children aged 1-59 months and rebound in the 5-9 years class, the cost per DALY averted is below US\$ 150 up to a rebound rate of 39%, up to an 84% rebound rate it is highly likely that the intervention will be DALY-averting, that is the DALYs averted by the intervention outweigh DALYs incurred through rebound rate. With reductions confined to children aged 1-35 months and rebound in the 3-6 years age class, the cost per DALY is highly likely to fall below \$150 only up to 2.5%, and with a rate in excess of 11% one can no longer be certain that the intervention is DALY-averting. Long-term surveillance included as part of ITN interventions is crucial with particular attention the age range over which rebound may occur.

With regard to the social-marketing approach of ITN programmes, it is clear that the method used in epidemic-prone areas and areas which play an important role in preventing spread to other areas, is not ideal. The net coverage rate and net retreatment rate could be low suffered by low affordability of households in many malarious countries in Africa. Therefore, the ability of preventing malaria explosion of the method is in question. Curtis and Mnzava (2000) expressed their opinions on social-marketing approach of ITN concerning of social aspect, noting that it would be deplorable if a switch from house spraying to insecticide treated nets was, in effect, a means of removing the responsibility for payment for malaria control from affluent taxpayer to the narrow shoulders of subsistence farmers, whose poverty arises partly from their affliction with malaria.

In fact, ITNs for malaria prevention could be viewed as a personal protective device rather than a vector control strategy. The intervention aims to create a relative malaria-safe personal environment via repellent of malaria vector rather than actively deal with the source of the transmission by killing vector larval and adult larval. The macro-environment - outside of the ITN - is still malaria dangerous. The strategy, whether using public delivery system or social-marketing approach, is appropriate for malaria prevention in endemic areas, where allow improvement of malaria situation at any pace without intense control of compliance rate, net coverage and retreatment rate, financial constrained governments shifting a bit of their responsibility to affordable households.

### **5.2.3 Residual House Spraying**

The comparison of efficacies of using RHS and ITNs against malaria vectors by Curtis and Mnzava (2000) reviewed data from spraying projects conducted in the 1950s-70s, some of recent insecticide-treated net projects in comparable ecological situation and six recent side-by-side comparisons of projects using ITN or RHS. They concluded that by all the entomological and malariological criteria recorded, pyrethroid-treated nets were at least as efficacious as house spraying with DDT, malathion or a pyrethroid.

For effective implementing RHS, it is necessary that the sprayed walls not be painted before the end of the transmission season. Curtis and Mnzava (2000) pointed out that spraying operations suffered from low staff morale and lack of public understanding and support. This could be corrected by comprehensive education programmes (Goodman et al, 2001). The compliance requirement is less intensive than ITNs. Also, RHS generally is less expensive than ITNs (Table 5.2), the most important feature of malaria prevention for most malarious countries. The biggest cost component of the strategy is insecticide costs would be less with no expatriate personnel participants. Further, RHS could offer a malaria safe macro-environment for epidemic-prone areas and economic-important areas. It is clear that RHS is the most important malaria prevention strategy for such areas. As Curtis and Mnzava noted, in epidemic-prone areas one can envisage a “fire-brigade” approach with a trained spray team equipped with spray pumps and insecticide, ready to go as soon as prediction indicators warn of an imminent epidemic. And it seems more feasible to maintain a capacity to react by spraying, than to maintain large stocks of nets for issue in the event of an epidemic.

It could expect that RHS is a more favourable approach for malaria prevention - it's simpler, faster and cheaper in concerning to all challenges of operation, management and finance - regardless to the authority (Roll Back Malaria) promotion of ITNs. However, the strategy is facing the fears of damaging environment, especially concerning the use of DDT.

#### **5.2.4 DDT**

The widespread use of DDT in the 1950s and 1960s all but eliminated malaria in several developing countries and saved an estimated 500 million lives by 1970 (*Economist*, 2000). Since then, its use has shrunk. Of the roughly 100 countries where malaria is endemic, only 23 now employ DDT to fight malaria (WHO, 1999). And that is frequently the fault of aid donors who help to finance the battle of against malaria (*Economist*, 2000). The Environmental Protection Agency banned DDT in 1972. Since then, American and international environmental and aid agencies pressured African, Asian and Latin American nations to abandon DDT, fearing its widespread use would endanger wildlife.

While there is some evidence that DDT causes environmental harm, damage occurred only during widespread agricultural use of DDT in the 1950s and 1960s, no study in the scientific literature has adequately shown any human health problem resulting from DDT (Bate and Okonski, 2001; *Economist*, 2000). Also, it is not likely that the tiny quantities used in house-spraying have any serious effect on the environment. Amir Attaran, another Harvard academic, estimates that the volume of DDT used to protect the entire high-risk population of Guyana for a year is equivalent to what a farmer might spray on to a single field of cotton, noted Dinan and Bieron (2001). By contrast, when DDT-spraying stops, the number of malaria cases frequently explodes (Dinan and Bieron, 2001; Roberts and Laughlin, 1997).

It is clear that DDT is the cheapest and most effective method for killing mosquitoes and many countries rely on its use for the control of malaria (Donan et al, 2001; *Economics*, 2000; Roger Bate and Kendra Okonski, 2001; Roberts and Laughlin, 1997). In 1990, cost comparisons of DDT and alternative insecticides for malaria control by the World Health Organization found DDT to be considerably less expensive than other insecticide, which cost 2- 23 times more on the basis of cost per house per 6 months of control. Recent research (Walker 2000) compared current price quotes from manufactory and WHO suppliers for DDT and appropriate formulations of nine other insecticides, showed that DDT is still the least expensive insecticide on a cost per house base. The recommended alternatives, pyrethroids, are four times as expensive as DDT and also less effective (*Economists*, 2000). It is critical for most malaria endemic countries, especially for very poor countries, like Zambia or Mozambique, where the annual health budget is less than \$5 a person (Dinan and Bieron, 2001). The government of India, within its National Anti-Malaria Program (NAMP), uses a number of insecticides, including DDT, malathion, deltamethrin, and others. NAMP concluded that it cannot use these more expensive insecticides with leaving tens of millions of Indians unprotected from malaria (Bate and Okonski, 2001).

Second, there is no need to drop DDT from crop dusters on acres of farms; low-dose use of DDT indoors is unlikely to cause any significant harm to the environment or people (Bate and Okonski, 2001). Third, DDT use for the last 6 decades in southern

Africa has not led to the development of resistance (<http://www.malaria.org.zw/pubs/vector1.pdf>). In contrast, mosquito resistance to synthetic pyrethroids has been reported in Ndumo, South Africa (Hargreaves et al. 2000).

DDT now is permitted in limited use. However, it is still far from ideal. That is because countries that use DDT for malaria control must record and report how much they use, how they use it and where they get it from (*Economist*, 2000; Bate and Okonski, 2001). This may not sound onerous, but in places such as Mozambique, where the annual budget for fighting malaria is less than 30 cents a person, any additional bureaucracy could prove to be a big drain on resources. As *Economist* notes, concern for the environment is generally an admirable thing, but obsession, at the cost of human lives, is of more questionable value.

#### **5.2.5 Environmental management**

The environmental management of malaria prevention has fewer environmental adverse effects. It often promotes the use of health and sanitation education of appropriate technologies, clean-up campaign, and community participation with an emphasis on self-help strategies for vector control (Ault, 1994). The cost and cost-effectiveness of EM from the study of Utzinger et al (2001) was impressive but did not reflect the true picture of it, as mentioned in sections 4.5 and 4.6.1. However, environmental management is often a cost-effective strategy for vector control for several reasons. As Ault (1994) noted, it relies on ecological principles and knowledge of the vector's natural history. The targeted approach makes the strategy less costly. Also, it can be integrated relatively easily with other control measures, and can be an appropriate technology chosen for the level of socio-economic development and resources available in a community. Further, its tactics lend themselves to community participation, which could substantially reduce the implementation costs compared with other interventions that need expatriate personnel. Moreover, when EM costs are embedded in the planning stages of developmental projects (e.g., dam and irrigation projects) or spread among multiple sectors of national economy (e.g., in both the health and agricultural sectors), the costs of EM can be reduced, making EM

a more cost-effective strategy than say a chemical-only control strategy that cannot spread costs and share resources outside the Ministry of Health. International bank such as World Bank often prefer to fund multisectoral projects and programmes. Thus, EM projects that engage professional and technical staff, labour, and other resources from multiple sectors can be cost-effective, particularly when capital (loans, grants) invested by development banks substitute for local (national) capital (Ault, 1994).

Environmental management could be easily integrated with other malaria control measures. It should be beneficial and preferable that integrate environmental management with spraying. The entomological survey that is necessary for EM could also benefit for effective and wise use of residual spraying. The targeted approach could have less wastage of spraying with fewer environmental effects, such as killing much fewer beneficial insects and causing much fewer injuries in other nontarget animal populations, meanwhile could also enhance the effectiveness of malaria prevention - environmental management of malaria prevention mainly is targeted at killing malaria vector larval, and spraying at killing malaria vector adults, therefore, the integrated approach could great reduce the malaria vector population and enhance the effectiveness of malaria prevention. The nature of targeted approach, full use local knowledge and resources, and community participation, lead the integrated strategy has lower costs and higher effectiveness, which could substantially increase the sustainability of rolling back malaria with fewer adverse ecology effects. It's also more preferable because of creating a much malaria-safer macro-environment with less restriction of human activities.

### **5.3 Choice**

To effectively choose malaria prevention methods, local health policy-makers should adapt malaria prevention knowledge both quantitatively (CEAs) and qualitatively (the pros and cons of malaria prevention interventions) at a local level, especially the local malaria epidemiological conditions, demographic factors, vector entomology and insecticide and drug resistance conditions. And, also the incremental costs, and therefore, cost-effectiveness, are affected by the degree of existing infrastructure. It

would be more cost-effective to direct resources to areas in which there is existing malaria control knowledge, skills and teams, such as existing residual house spraying teams, existing knowledge base of environmental management, existing village health worker teams or good coverage of nets, which are likely better-off areas.

Also one common issue reflected in CEAs to all malaria prevention interventions is compliance rate. Chemoprophylaxis for infants requires mothers cooperating with health village workers at home weekly or biweekly; RHS requires people not refusing spraying team and not painting the sprayed wall before the end of transmission season; environmental management requires community participations; and ITNs needs very active community involvement. The comprehensive education programmes, through which the compliance rate of most interventions could be well improved, is important to be noticed by health policy-makers.

## CHAPTER 6 CONCLUSION

### 6.1 Introduction

This dissertation overall objective was to review cost-effectiveness analyses of malaria prevention published from 1999 up to the middle of 2003, in the African context. The specific aims were:

- ❖ To outline the extent of malaria in southern Africa, its social and economic costs, to list the alternative preventive measures and current malaria control strategy
- ❖ To explain cost-effectiveness analysis (CEA) as a method of deciding between alternative means of preventing malaria
- ❖ To review a large number of studies of preventive method to deal with malaria, using a CEA framework, in order to show what methods are most cost effective

### 6.2 An Overview of Results

Malaria is a high priority for African health policy-makers, who are faced with complex dilemmas over the design of prevention strategies, the selection of interventions to improve treatment, and the allocation of resources between malaria control and other health care problems. When considered in conjunction with information on affordability and feasibility, evidence from economic evaluations can assist policy-makers in identifying interventions representing the best value for money.

Available CEA studies provide some guidance to decision-makers. According to the guideline that any intervention with a cost per DALY below US\$ 150 is an attractive use of resources, in low-income country (WHO, 1996), that all the malaria prevention measures assessed would be cost-effective ways to bring down malaria morbidity and mortality. The current CEAs review of malaria prevention covered interventions of ITNs, RNS, chemoprophylaxis for infants and environmental management. For infants, ITNs provided cost per death averted ranged from US\$ 2019 (Kenya 1) –

US\$2879 (Tanzania) and cost per DALY US\$ 111 (Tanzania); chemoprophylaxis provided cost per DALY US\$ 4.1 (Gonzalez et al, 2000) and cost per DALY of chemoprophylaxis plus iron US\$ 5.0. For child, ITNs gave cost per DA US\$ 1559 (Tanzania), cost per DALY US\$ 57 (Tanzania) and cost per sick child averted US\$ 61 (Kenya 1). For non-specific age-group, ITNs gave cost per infection averted US\$ 29, and RHS US\$ 9 (see chapter 4 and section 5.1.1).

Besides the difficulties of comparability of CEAs in concerning to comparable range of costs and effects, similar methodology, common effectiveness measures and various geographic settings, from current CEA review of malaria prevention, the review of Goodman et al (1999a) and the modelling study of Goodman et al (1999b), in general, chemoprophylaxis for malaria prevention is the least expensive among most cost-effective measures, followed by RHS 1 round a year, RHS 2 rounds a year, ITNs with net treatment only and ITNs with net provision and treatment. The cost-effectiveness of EM appears more expensive than ITNs with net treatment only and less expensive than ITNs with net provision and treatment. Using different delivery mechanisms for ITN programmes, socio-marketing approach appears more expensive than the public delivery system (see section 5.1.1 and 5.1.2).

With regard to cost-effectiveness analyses of malaria prevention, the current policy debates are limited by gross lack of information on the costs and effects of many interventions, the very small number of CEAs available, the problems in generalizing or comparing studies that relate to specific settings and use different methodologies and outcome measures, and the lack of evidence on the costs and effects of integrated/packages of measures. With regard to CEAs covered by current review, CEA of environmental management was the first study of the kind, and filled the gap of existing CEA knowledge base of malaria prevention. However, with limited data of costs and effects, the results estimated over-optimistic. And, the studies from socio-marketing settings of ITN programmes didn't explore the net coverage rate, the compliance rate and retreatment rate. Moreover, there is an urgent need to examine the changing effectiveness of RHS with other insecticides instead of DDT, especially in the places that used DDT before and is planning or switch to other insecticides. It is vital that all future trials of interventions also include economic components conforming to internationally accepted methodological standards, and that a much

greater effort be made to assess costs and effectiveness of routine delivery of interventions (see section 5.1.3).

Decision-making in concerning to malaria prevention is not only determined by quantitative studies of CEAs, but also qualitative investigation regarding to the application complexity of malaria interventions. Wide-use of malaria chemoprophylaxis is not recommended, since it could substantially increase the growth of drug resistance. Chemoprophylaxis is only promoted to be used by target groups, such as pregnant women and travellers (see section 5.2.1).

There are four factor which could reduce the cost-effectiveness of ITN - the compliance rate that related user inquiries, the management skills, the affordability both for individuals and governments and the delayed children's immunity acquisition. Further, the preference of the strategy is disbelieving because of the restrictive malaria-safe space. The strategy could be used in malaria endemic areas. The slow improvement of malaria situation and the burdensome process won't damage the situation further (see section 5.2.2).

RHS is generally less expensive than ITN, and this is most important feature of malaria prevention for most malarious African countries. It is more feasible for spraying reacting prediction indicators warn of an imminent epidemic by a trained spray team with spray pumps and insecticide than ITN reacting by maintaining large stocks of nets and issuing them. With regard to operation, management and finance, RHS is a simpler, faster and cheaper method for malaria prevention than ITN. The strategy is important for malaria prevention in epidemic-prone areas and economic-important areas, also creates bigger malaria-safe space for households in endemic areas (see section 5.2.3).

The big debate concerning RHS is the toxicity to environment, especially when concerned DDT. However, there are three important features of DDT: first, DDT is the cheapest and most effective method for killing mosquitoes. Second, there is no need to drop DDT from crop dusters on acres of farms; low-does use of DDT indoors is unlikely to cause any significant harm to the environment or people. Third, DDT use for the last 6 decades in southern Africa has not been faced with development of

resistance (<http://www.malaria.org.zw/pubs/vector1.pdf>). Many countries rely on the use of DDT for the control of malaria. When DDT-spraying stops, the number of malaria cases frequently explodes. DDT now is permitted in limited use with the requirement of detailed recording (see section 5.2.4).

Environmental management of malaria prevention relies on ecological principles and firm knowledge of the vector's natural history and has fewer adverse environment effects. The strategy appears cost-effective and is relatively easy to combine with other malaria interventions (see section 5.2.5).

The combination of RHS and EM could substantial increase the sustainability of rolling back malaria with fewer adverse ecology effects, and be the solution of wise and effective use spraying by sharing the knowledge of malaria vector entomology. The costs could be expected lower by the targeted approach and sharing knowledge, the effectiveness could be expected sustainable higher – EM mainly target at kill vector larval and RHS mainly target at kill vector adults (see section 5.2.5).

However, it is important to notice that to effectively fight malaria, there is no certain agreed one approach that could apply for all geographical and demographical varieties. Local health policy-makers should adapt these quantitative analyses of CEAs and qualitative investigations of malaria epidemiology, vector entomology, demography and insecticide and drug resistance at a local. And, also, incremental costs, and therefore, cost-effectiveness, are affected by the degree of existing infrastructure, knowledge and managerial skills. It would be more cost-effective to direct resources to areas in which there is existing malaria control knowledge, skills and teams, such as existing residual house spraying teams, existing knowledge base of environmental management, existing village health worker teams and good coverage of nets, which are likely better-off areas. Further, comprehensive education programme is greatly related with compliance rate in almost all malaria interventions, therefore, should not be neglected (see section 5. 3).

**Appendices**

**Appendix 1 Kenya 1 Gross outcomes (US\$) – recalculation from the initial data**

	Gross outcomes
<b>Costs</b>	
Annual economic cost of ITN programme	148,856
<b>Effects (per year)</b>	
Number of persons protected	62,500
Number of all-cause child deaths (1-11 months old) averted	61
Life-years gained (LYG)	2,959
Discounted life-years gained (DLYG) at 3%	1,525
Number of all-cause sick child visits (<5 years) averted	2,025
Number of ITNs	45,667
<b>*Cost-effectiveness</b>	
Gross cost per person protected	2.38
Gross cost per all-cause child death averted	2440
Gross cost per LYG	50.31
Gross cost per DLYG at 3%	97.61
Gross cost per all-cause sick child visit averted	73.51
Gross cost per ITN	3.26

\* This part is recalculated

**Appendix 2 Kenya 1 Gross outcomes with retreatment once a year**

<b>Costs</b>	<b>*Net economic costs (including community effect) reduced by 29%</b>
Annual economic cost of ITN programme	148,856
Net annual cost with community effect	88,644
Reduced annual economic cost of ITN programme	$148856 - 88644 * 29\% = 123149$
<b>Effects (per year)</b>	
Number of persons protected	62,500
Number of all-cause child deaths (1-11 months old) averted	61
Life-years gained (LYG)	2,959
Discounted life-years gained (DLYG) at 3%	1,525
Number of all-cause sick child visits (<5 years) averted	2,025
Number of ITNs	45,667
<b>**Cost-effectiveness</b>	
Gross cost per person protected	1.97
Gross cost per all-cause child death averted	2,019
Gross cost per LYG	42
Gross cost per DLYG at 3%	81
Gross cost per all-cause sick child visit averted	61
Gross cost per ITN	2.7

\* The information is from sensitivity study of retreatment once a year of the study

\*\* Recalculated from the result of the item of reduced annual economic cost of ITN programme

**Appendix 3 Cost-effectiveness ratios of KINET for infants (US\$ in 2000 price)**

			Reference
<b>Costs (1-11 months)</b>			
Total cost	149682		Hanson et al., Table 3
<b>Effects (1-11 months)</b>			
No. of death averted	52		Hanson et al., Table 5
No. of DALYs averted	1347.1		Hanson et al., Table 5
<b>Cost-effectiveness ratios</b>			
Cost per DA	2879		
Cost per DALY	111		

**Appendix 4 ITN retreatment rate of Tanzania study**

			Reference
Nets sold with initial treatment	65111		Hanson et al., p272
Years of programme implementation	4 (Jul 1996 – Jun 2000)		Hanson et al, p 270&272
Retreatment kit sold	24393		Hanson et al., p272
Treated-net year from nets and retreatment kit sold	*44752		Hanson et al, p272
No. of re-treated-net years needed	65111*3 = 195333		
Retreatment rate	*(44752 – 65111/2)/195333 = 6.3%		

\* The retreatment should be biannually  $(65111+24393)/2 = 44752$ .

**Appendix 5 Gross cost-effectiveness ratios of chemoprophylaxis and chemoprophylaxis + iron for malaria prevention (in US\$, 1996 value)**

Number of children provided by malaria intervention			
	Deltaprim + iron	Deltaprim	Reference
Total cost for health care provider	16998	16229	Gonzalez et al 2000, table 2.
Cost per child for health care provider	7.3	7.0	Gonzalez et al 2000, table 2.
Number of children provided by interventions	2329	2318	
Gross cost-effectiveness ratios of the interventions			
<b>Costs</b>			
Cost of intervention	8772	6424	Gonzalez et al 2000, table 2.
<b>Effects</b>			
DALYs saved	1759	1585	Gonzalez et al 2000, table 2.
Gross cost-effectiveness ratios			
Gross cost per child	3.8	2.7	
Gross per DALY	5.0	4.1	

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