Factors that affect the success and failure of InsecticideTreated Net Programs for malaria control in SE Asia and the Western Pacific.

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1. INTRODUCTION

Achieving high, appropriate and sustained bednet usage in the groups with significant morbidity and mortality is crucial to the success of any insecticide-treated bednet (ITN) program.

But how best to achieve this? Should we aim to cover everybody, or treat at-risk groups differently to the general population? Where bed nets are a new intervention, how do we motivate people to adopt the new behaviour of sleeping under nets at times of peak biting? How do we access difficult to reach groups?

For established programs, do we have a means of monitoring progress that is meaningful? And - both whether programs are successful or not - program managers will sooner or later be confronted with the question how long to continue with regular treatment and where to concentrate their resources. Do we have the data or criteria to make such programmatic decisions? If not, how can we obtain it?

In the last decade the use of Insecticide Treated Nets (ITN) has expanded greatly in the SE Asian and Pacific regions and often replaced residual spraying as the main vector control method. This report aims to invite discussion on the lessons from country programmes and scientific trials from past and current ITN programs in the SE Asian and Pacific regions.

ITN programmes, more than other vector control methods, depend to a large extent on the acceptance and active involvement of individuals and communities. Therefore the emphasis in this review will be on the human factors and on the human and social aspects of the more technical factors.

No doubt there exists a lot of knowledge and experience about these aspects among malaria program staff in the different countries, but this knowledge is not always systematically studied and reported, and therefore not easily reviewed or shared.

The contents of this preliminary report follow the terms of reference for this assignment:

1) to critically review the role of insecticide treated nets (ITN) for malaria control in East Asia and the Pacific;
2) to identify epidemiological, biological, social, environmental, operational and economic factors that have contributed to the success or failure of ITN in malaria control programmes;
3) to determine where and under what conditions ITN should and should not be used – the alternative being residual spraying or another form of vector control;
4) to produce guidelines that malaria control programme managers can use for targeting ITN and other vector control methods to the populations that will benefit most within a district or a larger geographical unit.
2. REVIEW OF ITN TRIALS IN ASIA AND THE PACIFIC REGION

Overview

While there are a very large number of studies of insecticide treated bed nets (ITNs) in Africa, there are relatively few well-conducted trials from the Asia/Pacific region. It is these local studies which are important to help determine the specific entomological, epidemiological, sociological, operational and economic factors affecting the success or failure of ITN in our region. Armed with such an evidence base, programme managers are in a better position to prioritise control efforts.

The review is mainly based on studies with human parasitological indicators, such as annual incidence, or slide positive rate from mass blood surveys. There are many more studies showing the entomological benefits of ITNs. Some of these have been included in the text – however, as an effect on mosquito populations does not necessarily translate into a reduction in human disease, these studies have not been included in the tabulation.

Which studies were reviewed?

A total of 47 trials and sub-trials\(^1\) in 9 countries in the East Asia and Pacific region have been reviewed. These are described in Appendix 1. Reports were identified through Medline and other Internet sources (see Appendix 2 - Search Strategy), as well as a manual search of bibliographies, review articles and directly from country and regional offices. A bibliography of over 100 references is also attached. This includes all of the reviewed trials plus many other articles of relevance.

Were the studies well designed?

To provide meaningful information, studies need to be well designed. Many researchers regard randomised controlled trials as the ‘gold standard’. There should always be an independent control group or groups for comparison, chosen for their similarity with the intervention area, and where the only major difference is the intervention. In studies of ITNs, controls would be people or villages where there were untreated nets, or no nets with or without another form of vector control such as space spraying. However, no two groups or villages are ever the same and will even without intervention change differently in time. Therefore the units of study should be randomised in some way, either at the individual level or some grouping such as village or district: the averages of two random groups will be more comparable. Studies with many separate groups in both the intervention side and the control side (called ‘units of randomisation’ or ‘units of allocation’) are much stronger than studies with few. For example, it is much more convincing to show improvement in 10 villages compared to 10 controls, than 1 district compared to 1 control, even if the total population numbers are similar.

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\(^1\) ‘Sub-trials’ are defined as individual trials within a programme of ITN trials, published together.
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Each of the studies listed were assessed according to the following checklist:

- Were the units randomised or quasi-randomised in some way?
- Was there an independent control?
- How many units of randomisation were there?
- What was the insecticide used, the dosage and the frequency of treatment?
- What was the period of the baseline and the follow-up?
- Was the data displayed in enough detail to allow independent evaluation?
- Did the results show a statistically significant benefit from ITNs?

Well-designed studies were categorised as showing an effect, or not. Studies with methodological flaws (such as no control group), but with results that suggested a positive effect were assessed as “probable”.

The 47 studies were very diverse making comparisons difficult. Importantly:

- There were several different insecticides used, PM in 29 studies (with a wide variation in the dosage), DM in 9 studies and a few studies each of EF, LC and DDT.
- Frequency of re-treatment varied from 6 to 12 months.
- The level of randomisation varied from districts/islands (11 studies) to villages/hamlets (30 studies) to individuals (6 studies).
- The period of baseline varied from a single MBS to 5 years of pre-study monitoring.
- The period of follow varied up from 3 months to 5 years.
- The indicators varied – MBS/prevalence in some, Annual Incidence in others.

Notably, there were no apparent associations between the above factors and the success or failure of the trials, suggesting that there are other factors at work.

Of the 47 trials reviewed, 17 (36%) showed evidence of effectiveness in controlling malaria, as measured by human parasitological indices. A further 13 studies (28%) showed a probable benefit, but had methodological problems that made it difficult to draw a firm conclusion. The remaining 17 studies (36%) showed doubtful or no benefit.

A number of independent experiences and observations that are individually not convincing because of a lack in the number of randomized units, are still valuable as “case histories”. A careful control is always needed because the malaria situation in a group will almost always improve by the attention from outside which increases diagnosis and treatment events. Taken together they could provide material for a meta-
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analysis, but comparisons remain difficult due to differences in methodologies and conditions.

Multi-unit studies may also be performed by adding new units one after another in time.

Delayed effects

There are quite a number of experiences that suggest that the effect of ITN on malaria gradually improves over the first 2-3 years. The reason for this is not clear (time needed to drain the ‘parasite reservoir’ or change of human behaviour?), but it needs to be taken into account when looking at trials where the follow-up time was very short. Most trials have only one or two years of follow-up.

It is concluded that ITN can be an effective tool for malaria control over a wide range of situations in the South East Asian and Pacific Regions, but are not always successful.

To determine which factors affect the success and failure of ITN requires a wider look by drawing on other literature, unpublished reports, personal observations and communications. A preliminary attempt is presented in chapter 3.
3. FACTORS THAT AFFECT THE SUCCESS OR FAILURE OF ITN

While forms of vector control such as residual spraying and larviciding can be applied leaving communities and individual families in a largely passive role, ITN programmes depend to a much greater extent on the acceptance and active involvement of individuals and communities. In many studies where the effect of ITN on the disease was disappointing there were still significant effects on vector parameters. This suggests that, while there was vector-insecticide contact, human-vector contact was insufficiently reduced.

Much of the early work focussed on technical aspects such as vector behaviour, insecticide dosage and schedules, dipping techniques etc. While these are important and should not be ignored, the success or failure of ITN programs may in many cases be related to human behavioural factors that affect coverage and proper usage.

In the last decade the use of ITN has expanded greatly in the SE Asian and Pacific regions and often replaced residual spraying as the main vector control method. No doubt there exists a lot of knowledge and experience about the human behaviour aspects among malaria program staff in the different countries, but this knowledge is not always systematically reported and therefore not easily reviewed or shared.

Moving from scientific trials to operational programs means that most experiences have to be sought in unpublished reports. Often these reports tend to focus on quantitative aspects while what we are looking for also is the description of human factors, which requires sociological and qualitative research methods. Social/behaviour studies are very group-specific and findings may not translate from one country, or site, to another. But the same applies to the vector and epidemiological aspects and these are more usually reported in great detail.

Many of the technical and operational issues related to ITN application also have human and social dimensions and therefore the two aspects can not be satisfactorily separated. Here we follow a conventional categorization that also does not escape this interwovenness, but is one way of scanning all possible factors:

Epidemiological factors
Biological factors
Environmental factors
Economic factors
Operational factors
Social factors
3.1 Epidemiological factors

3.1.1 Transmission intensity

For a considerable time it was thought that ITN would only be effective under conditions of low to moderate transmission and not powerful enough to have a measurable impact in areas with intense transmission. This would be expected on theoretical epidemiological grounds because the relation between transmission intensity and malaria morbidity and mortality is not linear. See e.g. the paper by Lengeler, Smith et al (Lengeler 1997) and halving the inoculation rate in a “saturated” situation may not have an appreciable effect on disease prevalence or incidence. However, the real shape of this curve is rarely known and many trials in Africa (Choi, Breman et al. 1995) and some in Asia (PNG, Khanh Phu, Vietnam) do show significant effects also in holoendemic situations.

An important related issue that has affected the discussion pro and contra ITN application is the possibility that the reduction of immunity caused by imperfect transmission reduction would be accompanied by increased or, especially, more severe morbidity. This discussion is as old as the heydays of DDT spraying and Molineaux (Molineaux 1997) argues on epidemiological grounds that “a reduction of the EIR will, other things being equal, always result in reduced total mortality”. In SE Asia and the Pacific early diagnosis and adequate treatment (EDAT) increasingly prevent that malaria disease leads to deaths. However, it may well be that more difficult to treat complications like cerebral malaria emerge in areas where it was rare before.

These considerations can nowhere form an argument against the deployment of ITN programs, but they do stress the importance of an approach that leads to sustainable transmission reduction and a concomitant strengthening of EDAT.

3.1.2 Stratification and population at risk

Choice of populations at risk

Countries will wish to make rational choices of where to apply ITN programs to maximize the prevention of malaria cases. A good surveillance system would indicate which populations are most at risk, but surveillance is often absent or deficient in the remote areas where malaria typically occurs.

There may be good reasons that ITN programs are not first initiated in the areas with most malaria. The highest malaria burden is often incurred by remote communities where the health system is weak. There are examples where the map of ITN application correlated more with the presence of NGO activities than malaria risk (e.g. until recently in Cambodia).
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The health promotion component of ITN programs as well as the organization of distribution and (re-)treatment requires trained and motivated local health staff or volunteers. ITN introduction may need to be postponed until the health system is sufficiently strengthened, while in the meantime mobile teams can provide periodic diagnosis and treatment and perform residual spraying activities.

Countries use different approaches to stratify their malaria zones and this affects the choice of priority populations to apply ITN programs. Where the stratification can not yet be based on countrywide comparable and up-to-date malaria surveillance indicators, there is usually a body of historic experience and epidemiological insight into what are the areas and groups most at risk.

**Stratification**

Most malaria stratifications for Asia combine elements of landscape and human ecology which yields basic typologies such as:

A. Coastal zone  -  (*An. sundaicus, An. subpictus*)
B. Rice field zone (flood plains, delta’s)  -  (*An. sinensis, An. aconitus*)
C. Hilly / mountainous zone (forested or deforested and replanted, etc.)
   a. Cultivated valleys, larger deforested areas, plantations of rubber, coffee, tea or fruits, wet rice on terraces or irrigated along streams. (*An. minimus, An. aconitus*)
   b. Forest fringe: subsistence farming, often ethnic minorities, maize, dry rice, cassava. Also hunting/gathering forays in the forest.
   c. People of various origins who spend various times in the forest for widely different reasons/occupations.

The malaria situation in the hilly/mountainous zone is most complicated and any subdivision in human groups based on occupation/behaviour, ethnic background, distance from houses to the forest, strength of forest dependency etc. remains somewhat unsatisfactory. A dominant factor for malaria risk is frequency of overnighting in the forest (often in makeshift shelters or without shelter at all) and the distance of settled people from the forest. But the ‘distance from the forest’ changes by deforestation and reforestation. Plantations replacing the forest may, or may not be a conducive habitat for malaria vectors.

The people temporarily overnighting in the forest have various origins and can not be defined as one group. They incur ‘part-time’ high malaria risk but otherwise can belong to any other group or zone. Forced or voluntary resettlement of large groups can change their malaria risk as well as the situation in a certain area almost overnight.

In lieu of a stratification based on actual malaria indicators, Cambodia used the distance of villages to forest (or more precise: “those villages from which, within a distance of 500 m, forest could be seen over more than 180 degrees around”) as a priority indicator for ITN application and used a GIS to locate those communities.
There is no consensus among countries in the region about criteria for ‘population at risk’ (see WPRO – VMP website). Papua New Guinea considers 100% of its population at risk, the Solomons and Vanuatu more than 95%. Vietnam also uses a wide criterion: “Population living in areas where malaria transmission has occurred in recent years, including local people and people coming from outside.”, which in 2000 included about 30 million people, which amounts to 39% of the total population. However, in Vietnam it is historically nor at present intended to protect more than about 12 – 15 million people by vector control. Most countries divide the population at risk into high, moderate and low risk areas.

Once a large proportion of the population most at risk are covered by ITN for some years and malaria incidence or outbreaks have become rare, it is naturally desirable to cut back in insecticide use by interrupting treatment. This is now practiced for instance in the northern part of Vietnam. Criteria are that the local health system is well trained in EDAT and a good reporting system is in place to monitor the situation. In several districts a system of rotation over villages is used, which can also be assumed to delay the possible development of pyrethroid resistance (pers. comm. Tran Duc Hinh).

It is likely that similar, but locally differing, strategies are applied in China, which has the longest history of ITN application over large areas. However, we have not been able to find reports about experiences and criteria used.

3.1.3 Full coverage versus targeted approaches

Full coverage

Are we looking to achieve universal coverage (aiming to use a similar approach to whole populations or communities)? There are several reasons to go down this path. Firstly, the malaria situation may be such that we should strive to see that everyone is protected. Secondly, studies have shown that only with coverage above a certain level the vector populations are affected so that even the people still sleeping without a net derive some protection (“mass effect”). Furthermore, it may well be that while some groups are likely to benefit more than others from an effective ITN program, we can more easily reach them with a program targeting the whole community.

A common approach to universal type programs is firstly to conduct a census of each village/community, then to return and distribute the calculated number of nets. Usually, initial net treatment is done in bulk, with communities providing some labour. Nets may be free or subsidised. Additional nets may be available for purchase for those who want and can afford them.

The attraction of such programs is that they are administratively consistent. Teams can move from one village/community to the next, using the same approach at each site. However, it is rare to get high levels of usage in all segments of the population. Even
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within a village, there are groups with different behaviour, beliefs and motivations and the “mass effect” may not be strong enough to compensate partial compliance.

**Targeted strategies.**

An alternative or supplementary approach is to put greater effort into protecting identified high-risk groups. By segmenting the population in this way, resources can be directed to achieving the maximum benefit.

Who then are the target groups? Generally recognised risk groups include pregnant women, infants/children, forest and other migrant workers. Local data on morbidity and mortality in these segments of the population is required to justify a targeted approach, and should be sought if it is not available.

Once identified and verified, how do we reach these groups? This may require different and innovative approaches. There are many good examples of these from the regions.

For example, pregnant women and their children may be reached by distribution and health education through antenatal clinics, where ANC uptake is high. Such women can be highly motivated to protect themselves and their infants. A family-sized bed net for each new ANC attendee, either as a gift or highly subsidised and delivered with appropriate health promotion messages, can be a very effective method of achieving good usage. However, women most at risk may be missed by this approach, as proportionally more don't have ANC.

Programs aimed at schools, for example requiring all boarding students to have and use bed nets, can be coupled with a school health education program about malaria control. Taking this a step further, schools can be required to annually meet certain standards for environmental health and hygiene to be allowed to operate. This can cover bed nets, reduction of mosquito breeding sites (eg for *Aedes*/dengue), in addition to water and sanitation etc.

Some workers may be reached through their employers, e.g. mining and forestry companies. Education programs with employers can emphasize the benefits to the company of a healthy workforce.

Another important risk group are refugees and other displaced people who often flee to forested areas. These groups require special attention for many reasons and ITN use can be integrated in these programs.

### 3.2 Biological factors

#### 3.2.1 Vectors
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**Vectors: species and species groups**

The main vector species (groups) that malaria programs have to deal with in respectively the East Asia and Pacific regions are:

- *An. minimus*
- *An. dirus*
- *An. sundaicus*
- *An. sinensis*
- *An. anthropophagus*
- *An. balabacensis*
- *An. maculatus*
- *An. sawadwongporni*

There are no convincing indications from the literature so far that among these ‘species’ (of which many are species groups) there is any for which ITN’s wouldn’t contribute to malaria control. This is not to say that ITN’s have the same effect on all (see next sections).

**Vector behaviour**

Most effect of ITN on a vector’s lifespan and population numbers can be expected with species that are highly endophagic, anthropophilic and bite mostly during the time when people are under nets. In S.E. Asia there are no species that consistently combine all these favourable characteristics and hence these factors are very important to consider in the context of ITN application.

**Biting time and endophagy**

There can be clear species specific differences in biting hour even between the closely related species, for instance in the *An. dirus* group (Baimai, Kijchalao et al. 1988) and one biological species can show different behaviour in different environments and seasons. And there is evidence that mosquitoes can adapt to some extent to vector control applications: both IRS and ITN can lead to exophagy and earlier biting.

Moore et al (Moore, Zunwei et al. 2001) reported in 2001 that despite a control program, malaria incidence in Yunnan Province in China has increased. In their study of various light traps, they found an abundance of early active mosquitoes in living areas, concluding that personal protection measures may be required in the early evening, to supplement bed net use.

In a paper exploring the peak biting times of parous and nulliparous *An. farauti* in Solomon Islands, Bockarie and colleagues found that parous females have a tendency to bite later than nulliparous ones (Bockarie, Alexander et al. 1996). They hypothesize that, quote: “in areas where *Anopheles* mosquitoes have a late-biting cycle and low parous rate, exposure to mosquitoes infected with *P. falciparum* during the pre-bedtime
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period (18:00-22:00) is very low. This hypothesis could explain why insecticide-treated bed nets protect children better in areas of seasonal transmission, where nulliparous females tend to predominate, than in areas of perennial transmission, where parous females are usually more numerous…” (end quote).

In Vietnam, malaria caused by *An. minimus* A responds in general well to ITN, but there are differences in biting time as well as differences in peak seasons in different areas of the country. In central Viet Nam (Marchand et al., in prep.) *An. minimus* A virtually disappeared from a holoendemic village where it was previously responsible for more than 80% of all infective bites. The abundance of the other main vector, *An. dirus*, was not affected. In this area *An. minimus* bites later (and mostly endophagic) than *An. dirus* (both indoors and outdoors). After net treatment, both species showed slight shifts towards earlier biting: *An. dirus* from 45% to 65% and *An. minimus* from 15% to 23% biting before 22h. However, in a more southern malarious area (Binh Phuoc province, Chambers, pers. comm.) *An. minimus* is the earlier biter of the two - it is not known if this is an effect of ITN. A more extreme case of early biting in *An. minimus* A (80% before 22h) has recently be reported by Sochantha and Hewitt (pers. comm.). However, this was only happening at the end of the rainy season.

Although there are so far no established cases that show failure of ITN because of an adaptation to early biting, it is clear that this factor needs to be studied and monitored carefully. It is probable that such changes initially come with a price of survival value, hence longevity and transmission capacity. But, as in the case of insecticide resistance, the possibility can not be excluded that mosquitoes evolve ways to overcome this.

A notoriously difficult to control vector, due to its exophilic habits, is *An. dirus*. But ITN trials in areas where this vector plays a big role show both positive and neutral results on malaria disease indicators. In several well-studied cases with disappointing results (Dak’r Lap and Khanh Phu, Vietnam) the main reason is that people get mostly infected in the forest where they venture unprotected by ITN. In the forest people fail to use ITN against *An. dirus* – rather than that ITN fail against *An. dirus*. It appears that what for *An. dirus* looked like a biological problem for the application of ITN, on closer look appears to be a human behaviour factor (‘exophilic people’ among exophilic vectors).

**Anthropophagy/zoophagy**

In Asia there are no vector species that are obligatory anthropophilic and both IRS and ITN may act as selection pressure for more zoophagic behaviour. This is obviously beneficial from the viewpoint of malaria control.

**Summing up, even when vector population size or longevity is not affected, or when behaviour changes are induced, consistent use of ITN can still be expected to reduce human-vector contact. With high ITN coverage the sporozoite rate, and hence EIR, may still decrease as a result of fewer mosquitoes picking up gametocytes.**
3.2.2  **Insecticide resistance**

Another relevant aspect where species differ markedly is in insecticide resistance. *An. sundaicus* and *sinensis* are more likely to be exposed during their aquatic stage to pyrethroids used in agriculture and therefore sooner develop resistance.

The possibility of mosquito resistance to insecticides is an important consideration. In many areas, there is no immediate cause for concern. For example, Kang et al (Kang, Gao et al. 1995) point out there is no evidence for any build up of resistance to deltamethrin in malaria vectors in China from areas where millions of bed nets have been treated annually for up to 7 years. However, a strain of *Culex quinquefasciatus* which had been bred in a factory in which volatile pyrethroids are handled had developed unequivocal resistance to deltamethrin.

Similar as in the case of DDT used for residual spraying, the biggest threat is in those vectors that are exposed to similar insecticides used in agriculture. Rice field breeding mosquitoes (e.g. *An. sinensis*) are more likely to develop resistance than species that breed in rainwater or isolated forest water collections far from agricultural plots (e.g. *An. dirus*).

Some cases of pyrethroid resistance are known in Anophelines, however, notably in *An. gambiae* in West Africa. Hence, Curtis *et al* (Curtis, Miller et al. 1998) urge that effort should be made to find methods of responding to, or preventing, the emergence of pyrethroid resistance in the Anopheles vectors. Rotation of insecticides or the simultaneous use of different insecticides (in a pattern or as a mixture in every net), might be effective. However this has not been studied deeply enough yet and the problem is that mosquitoes show cross-resistance against the different pyrethroids.

Tests to monitor physiological resistance will not show whether behavioural changes are induced by ITNs. Similar (again) as in the case with residual spraying in the past, behaviour changes might be induced that cause the insects to avoid contact with insecticides, notably towards exophagy and shifts in the time of biting. Although this might make ITN less effective, it would certainly not make them useless, as these behaviour changes are likely to come with a loss of fitness. Induced exophagy/exophily may alter the transmission epidemiological picture in unpredictable ways, but consistent earlier biting would be a serious threat.

The reasonable course of action is to include entomological procedures for regularly monitoring for the emergence of pyrethroid resistance in sentinel sites, as a standard component of malaria control programmes. Switching to another insecticide would be a feasible and effective response. However, the problem is still to find a suitable alternative without cross-resistance to the pyrethroid used before.

Monitoring of mosquito biting behaviour is also indicated for routine monitoring. Although also here there is no obvious effective response to changes, except increased
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efforts towards the use of repellents when people are not under a mosquito net. It will remain one of the important entomological factors to study when ITN fail or become less effective in reducing malaria disease.

3.3 Environmental factors

3.3.1 Geographic and climatic

There appears no geographic region or country where ITN fail throughout. Of course, countries differ in the organization of their preventive health service, malaria program and the resources and possibly the political will to invest in effective ITN programs, but this should be considered under the operational or social factors.

There are many examples where the use of ITN was less during the hottest season because the restricted air flow makes sleeping under a net inconvenient.

There are also examples where coldness can interfere: some poor people in the Central Highlands in Vietnam had a lack of blankets and use the nets instead.

None of these situations presents a convincing contra-indication for the use of ITN and are more properly discussed under the human factors.

3.3.2 General biting nuisance

The level of biting nuisance by insects in general (i.e. mostly non-vector species) can be regarded as an external environmental factor that has a positive effect on the proper use of bed nets by people. However, there is some evidence that ITN usage patterns change depending on perceptions of mosquitoes as a biting nuisance, or as a vector of disease. This is discussed below.

3.4 Economic factors

3.4.1 Cost-effectiveness

The use of ITNs has been shown to be cost-effective in several situations.

The cost-effectiveness of lambdacyhalothrin-treated nets in comparison with conventional DDT spraying for malaria control among migrant populations was evaluated in a malaria hyperendemic area along the Thai-Myanmar border. (Kamolratanakul, Butraporn et al. 2001) The impregnated net program was most cost-effective (US$1.54 per 1 case of prevented malaria). Spraying with DDT was more cost-effective than malaria surveillance alone ($1.87 versus $2.50 per 1 case of prevented malaria). These data suggest that personal protection measures with
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insecticide-impregnated mosquito net are justified in their use to control malaria in highly malaria-endemic areas in western Thailand.

In the same study area, information about consumer costs was obtained by patient interviews at all levels of the health care system in the study area. (Butraporn, Kamolratanakul et al. 1999) Analysis showed that the impregnated-net program was more cost-effective than the DDT-spraying program or surveillance alone (US$ 0.59 vs US$ 0.74 vs US$ 0.79 per 1 case of prevented malaria).

The same group (Kamolratanakul and Prasittisuk 1992) (Kamolratanakul, Dhanamun et al. 1993) conducted a randomised, double-blind field trial to compare the economic impact of permethrin-treated nets with that of untreated nets as a method of malaria control in seasonal agricultural migrant workers in the eastern rural areas known to be highly endemic for multi-resistant \textit{Plasmodium falciparum} infection. The impregnated nets program was cost saving as well as offering improved effectiveness. The net benefit of using a treated net was US$1.17 per worker from the Malaria Division's perspective and US$1.61 per worker from the worker viewpoint. The authors conclude that use of impregnated nets with large-scale primary health care programs likely is the most cost-effective and cost-beneficial method for controlling malaria in eastern Thailand.

In Solomon Islands Kere and Kere (Kere, Arabola et al. 1996) compared the cost of DDT house spraying and permethrin-impregnated bed-nets for a population of 7712 in Florida Islands, Solomon islands. DDT spraying cost SIS8.53 (~US$1.30) per capita per year while the permethrin-impregnated bed-net operation annually cost SIS3.85 (~US$0.60) per capita.

3.4.2 Cost recovery and sustainability

In the sections 3.5.6 and 3.6.3 it is discussed why full cost recovery and community self-reliance should in general not be expected and that ITN maintenance will require continued (government) program inputs.
3.5 Operational and technical factors

3.5.1 Coverage assessment

*Reported usage versus observed usage.*

What is an effective level of coverage? A figure of > 80% is often quoted, without much of an evidence base in the Asia-Pacific region. Coverage is mostly assessed using an 'administrative' method, i.e. a calculated figure, based on number of nets distributed or retreated, at some ratio to the population. A ratio of 1:2.4 is commonly used. This is a simple system that provides some useful information. However, there are several problems if we rely only on this approach. Nets may not be used or may be damaged and hence less effective. Number of years in use, and since last re-treatment are also important.

The newer indicators take this into account by including only the number of nets initially treated (i.e. newly distributed) and number retreated in the last 12 months rather than cumulative count of nets distributed.

The use of a fixed ratio of people per bed net does not account for social and cultural differences. For example in boarding schools or for forest workers, the ratio should be 1:1. In addition, many communities will appreciate a choice between single and double (or family-size) nets: families with young children do well with a family size net, but for older people who live together with adolescents single nets are more suited. Consideration should be given to determining and using locally appropriate ratios.

Even if coverage can be accurately calculated, it will give only an upper limit to the actual usage. Accurate usage rates are required to determine what proportion of a population needs to use nets to reduce malaria transmission, and to evaluate the effectiveness of promotional programs over time. Usage, if it is to be determined, must be by questionnaire or by observation. Reported coverage and even reported usage may exaggerate the real situation. Direct observations, rather than self-reported behaviour, may be essential to accurately gauge bed net usage rates.

One study (Leake and Hii 1994) used both observational and survey methodologies to identify human behavioural factors which may have contributed to the poor results in an earlier bed net study (Leake and Hii 1989). Villagers reported a significantly higher net usage rate than that observed directly, confirming that self-reports need to be validated in some way.

Observational studies are expensive, intrusive and time-consuming and that is why their role is so far mostly limited to formative/operational research and 'trouble shooting' e.g. in situations where malaria continues to be a problem despite high coverage levels. However, observed coverage remains as the most directly relevant operational indicator.

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2 If 2.4 persons/net is regarded as ‘full coverage’, 80% coverage would imply 3.0 persons/net globally.
in any ITN program. Ideally it should be combined with an indicator of insecticide presence in nets (Verle, Ruyen et al. 1998), so as to give an estimate of coverage by treated nets. The disadvantage of intrusiveness and costliness could be mitigated if it becomes part of a regular service to maintain and replace ITN (see also 3.5.6).

3.5.2 Netting material, insecticides and washing

Netting material

Nylon, polyester, polyethylene, cotton and other materials.

In technical respect the choice of the netting material is important in relation to the insecticide to ensure a combination that gives optimal insecticidal effect, residuality and wash-resistance. Fibre made from polyfilaments of synthetic materials adsorb pyrethroids best and give the best insecticidal effect. Cotton absorbs more but more of the active ingredient is inside the fibers and therefore not ‘available’ to insect contact.

Insecticides used to treat nets

Although some trials have been with DDT (the first chemical applied to nets), the pyrethroid insecticides are favoured for the purpose of treating nets, because of their high insect and low mammal toxicity. Within that group there is a choice of chemical variants and formulations which differ in toxicity, repellency versus killing effect, residuality, washing-resistence and handling safety (for re-treatment).

The recommended and most commonly used insecticides are Permethrin, Deltamethrin, Lambda-cyhalothrin and (least) Etofenprox. Microencapsulated formulations have improved washing resistance and handling safety.

The choice and dosage of insecticide does have relevant effects on the vectors, notably the balance between repellency and killing effect. Curtis and Mnzava (Curtis and Mnzava 2000) suggest that the use of non-irritant insecticides in the past, such as dieldrin and malathion, because of their strong insect-killing effect, could be the reason that IRS was so much more effective in the past than at present with the newer pyrethroid chemicals. If this is true, the ITN method may be much more effective if less irritant insecticides could be used. Some trials with carbosulfan in nets seem to support this (Guillet, N’Guessan et al. 2001).

However, for practical purposes the main consideration so far has been to obtain optimal safety, residuality and wash-resistance. A comparison of five insecticides in the north, centre and south of Vietnam (Tran Duc Hinh 2000) showed, besides differences between the insecticides, considerable differences between the different zones where the nets were used. In this trial Lamdacyhalothrin CS and Alphacypermethrin SC emerged as superior in general stability.
Permethrin was originally preferred because of the lack of side effects like skin irritation on humans (esp. during insecticide handling and treatment), but its insecticidal effect persists only about 4-6 months, requiring twice-yearly treatments in areas with year-round transmission. Lambda-cyhalothrin CS and Alphacypermethrin SC can last around a whole year.

**Washing of nets**

It is unrealistic to expect people not to wash bed nets from one re-treatment to the next. However, studies of washing conventional ITNs give differing results.

The results of research in China (Zhang and Yang 1996) show that residual effect of unwashed deltamethrin-impregnated bed nets (15 mg/m²) could last for 13 months. When an impregnated bed-net was washed for the first time at the 12th month, its mortality effect on *An. sinensis* was reduced quickly to lower than 50%. The residual effect could last for 2-3 months when washed at the 6th month, but was lost when washed for the second time at the 12th month.

A village scale trial was carried out in Koraput District of Orissa, India (Das, Das et al. 1993) to evaluate the efficacy of bed nets impregnated with lambda-cyhalothrin, at the dose of 25 mg/m². The insecticidal effect of bed-nets was retained up to six months. Washing of bed nets by the community did not affect the efficacy. The acceptance and usage was better with impregnated nets as compared to ordinary nets.

Some newer, microencapsulated formulations show considerable improvement in wash resistance (Curtis, Myamba et al. 1996; Tran Duc Hinh 2000), but most hopeful is the recent innovation of nets pre-treated with long-lasting impregnations (“Permanets”). Trials are still being conducted but preliminary results suggest that these nets were still effective after 32 washings (WHOPES).

### 3.5.3 IEC, social research and community participation

**IEC**

A strong health education/promotion component is essential in ITN programs where nets are introduced for the first time. This costs an amount of time and human resources that is often not compatible with large-scale ITN expansion programs of limited duration. The translation of IEC material in ethnic language and adaptation of pictures to the particular cultural situation is necessary, but often not enough in itself. As in other health programmes that aim at behaviour change, health promotion works most effectively by face-to-face communication at locally and culturally appropriate times and occasions, by people who are accepted and respected by the community (specially trained village health volunteers, etc.).
Community needs are important

Programs that take community requirements into account have a better chance of success. For example, net design (size, shape, colour) may be an important factor in achieving high usage rates. Community perceptions relating to re-treatment are very important. Such issues can be identified through community consultation/social research.

The value of participatory social research

Social research is essential in the development and strengthening of ITN programs. A range of participatory and qualitative methods, such as observation, structured interviews and focus group discussions can yield valuable, in-depth data on behaviours related to bed nets, and other night-time activities that increase malaria risk, such as television viewing that keeps people awake and out of bed-nets. The information gathered provides a means to strengthen programs.

Participatory social research puts the community and their perceived needs at the centre of the activity. The participatory process of the research can lead to a strengthening of outcomes, as communities discuss and obtain a better understanding of the issues.

However it is important to recognise that a change in knowledge and attitudes is not enough to achieve a change in behaviour. Behaviour change is often slow and subtle, and will only occur if there is an environment that positively supports and reinforces the change. In the case of ITN, this could be achieved through community participation or feedback in monitoring activities.

Behaviour change objectives should initially be limited to identified key points, and should be targeted at identified risk groups. It is a common mistake to try to address too many issues at one time.

Social research and participatory approaches require substantial investment both in time and resources. This investment should reap benefits, not only in the form of more effective programs, but also in making communities and individuals more self-reliant in taking care of their own health situation in general.

3.5.4 Role of public and private sector and target group

Malaria in Asia and the Pacific is a rural disease, strongly correlated with poverty, remote marginal areas and a weak local health system. For communities that incur most malaria risk and enjoy high immunity, malaria prevention may not rank equally with several other daily priorities, like ensuring food safety for the next few months. Nevertheless, poor health is one of the factors keeping these communities at the bare edge of survival. Therefore a public health agency will be needed to take the lead in
stimulating preventive health measures and in the case of ITN programs to ensure equitable coverage and timely re-treatments.

The design of effective ITN programs has to be based on good knowledge of local perceptions and customs. Wherever possible the communities need to be involved in the activities as this helps to make them aware of what they can do themselves to improve their health situation. These requirements point to capacities and skills (skills for social research and a participatory attitude) that may still have to be developed in the preventive health service. Strategic partnerships with NGOs or other local organisations (Red Cross for instance) and sectors have proved helpful.

The relative simplicity and safety of ITN use and insecticide re-treatment makes it in principle possible to be maintained by the target communities and individuals themselves. Although this is an advantage over residual spraying, which needs to be done by professional staff in every house, and may save program manpower at the implementing level (assistance with distribution, community mobilization and dipping activities, etc.), experience shows that good coverage can not be sustained by communities alone.

In situations where people have a higher living standard there is scope of cost-recovery and for the role of public-private partnerships to achieve optimal distribution and availability of nets. Also this aspect is new for conventional health programme staff and would therefore require training and input of special expertise.

3.5.5 Phasing and scale (‘absorption capacity’)

After the realization that ITN form an effective contribution to malaria control, ambitious donors have often been tempted to design quick and large-scale introduction programs for ITN. There are several pitfalls with this approach. In many cases the local human resources who have to implement such massive projects are limited. Considerable time and resources would be needed to first increase and train human resources. This applies to program managers as well as local health staff. Quick massive bed net distributions can be expected to fail in setting up a system to ensure proper usage and awareness about the purpose under the target populations. If a limited workforce of program managers and implementers needs to initiate the activities over a wide area, they can not pay attention to local and regional adaptations, which threatens both effectiveness and sustainability.

A phased expansion seems most appropriate so that there is sufficient time to adapt strategies locally and plan towards sustainability.
3.5.6  Project versus sustained program approach (sustainability)

A ‘project approach’ is generally appreciated as the only effective way for the initial expansion of the use of ITN, but many countries are now facing the need to maintain the achievements and integrate them into routine malaria control operations.

Clearly, maintenance will be easiest in countries that have a strong, dedicated malaria control organization with permanent staff who were already used to yearly recurring spraying campaigns over large areas (Vietnam, China).

It seems best to plan for an organization and program that can sustain a yearly activity schedule that integrates re-treatment with replacement of nets and reinforcing health promotion (as well as retraining, improving diagnosis and treatment). This, however, also requires stable (government) funding.

How long should we continue to treat nets? There are epidemiological situations where after some time malaria incidence and vector capacity are reduced to such a low level that it would seem wasteful to continue to apply insecticide (China and Vietnam). This lucky state of affairs is certainly conceivable, for instance with vectors like An. minimus and in large areas with unstable malaria. Clearly this depends on the development of a good malaria surveillance and information system, although actual malaria indices would by no means be the only, or even most important, criterion. Under conditions of unstable malaria ITN may serve to prevent outbreaks and removing this protection needs to be carefully weighed. However, with clear early-warning indicators and prompt response capability, malaria control can be economized and insecticide use reduced to a minimum.

3.6  Social factors

This last category groups the social/human factors that have not yet been discussed in the other categories or deserve additional treatment.

3.6.1  Difficult to reach groups: culture, education, occupation and migration

Malaria among difficult to reach groups, such as illegal immigrants and indigenous groups living and working in risk prone areas requires special efforts to identify suitable control measures. The measures must be adapted to suit the particular conditions and environment and to different community groups. (Arasu 1992)

A study conducted in 1992 in Heping District of Quiongzhong County (Cai, Deng et al. 1995), a hyperendemic mountainous area, found that staying in the mountain (instead of returning to the village at night), using bed net and seeking medical service were three discriminating factors affecting local malaria transmission and control. Based on this, health education focused on changing the behaviour of staying in the mountains, increasing the utilization of mosquito nets and reinforcing the primary health care.
People overnighting in or near the forest have the highest parasite prevalence, but not always most malaria disease. The biggest group with high immunity are probably the farmers’ families who practice ‘swidden agriculture’ in the mountains and have their plots far from villages and health services. In Vietnam the government has since long been promoting a “settlement policy” to encourage these “semi-nomadic” people to live in permanent villages where public facilities as health stations and schools can be provided. However, the natural environment in the mountains still forces a part of them to have their agricultural fields far from the villages, where they build simple temporary shelters where they stay at least part of the year. People are advised and encouraged to bring their nets there, but the coverage of disciplined usage appears always much less than in the villages.

- a shortage of nets will let them keep their valued nets in the more secure village house, the shelters or plot huts are often minimal;
- it is cumbersome to carry and set up the nets;
- adult people are immune and don’t fear malaria much.

Less or non-immune people who venture in the forests for logging, mining or illegal activities are at a much higher risk of becoming ill, so they will more readily use whatever protection that is available to them. The problem here is to identify and reach them. Reports from Cambodia about social marketing of hammock nets indicate that these problems may not be unsurmountable.

However, the risk group in SE Asia that is most difficult to protect are ethnic minority people who spend periods in the forest for hunting or the collection of forest products (bamboo, herbal medicines, fishing, etc.). They live in the most remote areas, have little contact with health services, and this combines with cultural barriers and age-old habits in which certain health risks are accepted as natural. They often don’t even build a shelter in the forest and sleep unprotected around a small fire (unpubl. obs. Khanh Phu project, Vietnam).

In Vietnam, where malaria is relatively well under control now, these groups (forest plot hut dwellers and forest hunter-gatherers) incur most of the remaining malaria mortality and they may even be responsible for maintaining transmission in persistent foci (“hot spots”). Where these groups belong to more settled communities they are best approached as a subgroup that requires special attention within a ‘universal community coverage’ strategy. Spraying is usually no alternative to ITN here because “there is not much to spray anything on” in the forest. Pilots with the use of repellents, ‘standby drugs’ for self-treatment and special arrangements to provide treatment before and after going to the forest are being tried, but with little success so far. To mobilize the participation of these groups in malaria control probably demands more than the usually available attention.
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3.6.2 Community perception and needs

Simply making the nets available to the villagers does not necessarily make them a desirable commodity. Nets may not be used as intended for a variety of reasons. For example, people may not share our beliefs of the causation of disease, and the relationship between mosquitoes and malaria. Understandable where disease incidence and biting nuisance appear not clearly related.

Studies in rural communities in central Malaita, Solomon Islands (Yohannes, Dulhunty et al. 2000) (Dulhunty, Yohannes et al. 2000) showed that reasons why people used bed nets differed within a community, and this affected patterns of usage. Children from households where bed nets were used for malaria protection were more likely to sleep under bed nets than children from households where nets were used as protection from mosquitoes only. Also, respondents who used bed nets as protection against malaria were more likely to use bed nets at times when mosquitoes were few.

A study in Ratchaburi Province, Thailand (Sri-aroon, Rauyajin et al. 1998) showed that the use of impregnated bed nets was significantly related to the factors such as knowledge of malaria prevention, perception of benefits of the use, and the receipt of information about the impregnated bed nets from malaria workers.

A simple health promotion message administered by village midwives raised bed net usage to over 60% in trial hamlets in north Shan State, Myanmar (Lin, Aung et al. 2000).

All this points to the importance of a strong health education/promotion component in ITN programs where nets are introduced for the first time. The translation of IEC material in ethnic language and adaptation of pictures to the particular cultural situation is necessary, but often not enough in itself. As in other health programmes that aim at behaviour change, health promotion works most effectively by face-to-face communication at locally and culturally appropriate times and occasions, by people who are accepted and respected by the community (specially trained village health volunteers, etc.)

The bulk of experience over the last decade in the SE Asian and Pacific region (with recent great expansions to indigenous populations in Cambodia, Laos) shows that nets are enthusiastically accepted by people who hardly used them before. Even if they are not really motivated, or believe, that it can prevent disease, they consider it as an increase in their standard of living and as a token of attention from the outside world. It should be remembered that many of these remote communities hardly receive any attention, at least not to their wellbeing.

However, where malaria is not perceived as a priority problem in a community, the availability and acceptance of nets may not automatically lead to consistent and effective use of the nets. Obviously, when health authorities decide on epidemiological data that a community is highly malarious, this needs not imply that the community regards this as their real priority. In fact, since most malaria is concentrated in the poor
and remote, agriculturally marginal, areas, this is more the rule than exception. Preventive health considerations often can not compete with the dependence on forest-based occupations for economic survival.

There are many observations and anecdotes about people who don’t use the nets when it is hot, use the nets as a blanket when it is cold, use them as fishing nets, or, after drinking alcohol, they don’t carefully sleep under their net, etc. Where TV or video is introduced especially young children stay awake outside their nets far longer than before. In many ethnic communities the teenagers don’t sleep with their parents but in the communal house. Although there are few, if any, studies which have attempted to quantify such observations, it is very likely that they are important factors for the impact of ITN on malaria in the community.

3.6.3 Side effects of ITN

There are no reports about appreciable negative side effects of ITN on people. The safety for humans while dipping nets with pyrethroids has been amply established and therefore the safety for the people sleeping under the nets is not an issue.

However, there is a need to study what happens in reality during routine retreatments: how much of the chemical is lost in the environment for instance.

The positive side benefits of ITN programs can be vast, especially when introduced to communities in remote areas which are among the most neglected populations in respect of health care. Even where these communities were covered by IRS before, the health education component and the establishment of a network of village malaria volunteers needed for ITN programs often provide an entrance point for other health programmes (see e.g. Cambodia, where ITN provision was soon coupled to Family Planning, Vitamin A and other activities). In many areas in Vietnam where DDT spraying has been performed for the people for decades, only in the ITN programs people were made aware about the relation between mosquitoes and malaria and thus that they can do something themselves to help prevent disease apart from swallowing pills.
3.6.4 Sustainability: cost recovery, re-treatment and replacement

*Free versus subsidised versus full cost recovery*

There are reasons for and against charging for nets, and there is no simple answer. In practice a mixture of approaches is usually required.

The arguments in favour of charging for nets include: it promotes a sense of ownership of the net; it discourages abuse of the program; and it helps to offset the cost of running the program.

Disadvantages include: the cost may be a disincentive leading to lower coverage, especially for poorer segments of the population (who may be at greater risk); the ownership of the net that comes with a purchase may instil a sense that "it's mine and you can't tell me what to do with it" especially regarding inappropriate use and re-treatment; program staff have to handle money.

From experience in Vietnam and many other programs, subsidized distribution seems in general the most favourable option. Especially when target communities for which the use of nets is new, are themselves involved in the decision making about acceptable prices and how to deal with the poorest community members, this stirred a lot of ‘heat’. Besides stimulating community participation and ownership the health education/promotion messages were more quickly absorbed. This is well worth to the additional (and often resisted) trouble for program managers and local health staff – forcing them to interact more directly with communities, in stead of regarding them as passive receivers of ‘care’. In addition it marks the nets from the start as a normal household commodity when they are expected to purchase on the private market once they start to wear and the introduction programmes have finished.

If we keep in mind that the goal is to achieve high coverage and usage rates, then a certain degree of oversupply is a good thing. We don’t mind if someone gets more nets than they are 'entitled to' provided that the majority of the nets are being used to protect someone.

In this regard, social research in different settings would provide useful information on the best approaches to adopt.

Full cost recovery, even when facilitated by revolving funds, has generally been disappointing. Especially in poor ethnic communities where (like in SE Asia) the use of nets is new, some subsidy to motivate people and give them a chance to get used to sleeping under nets is necessary.

Malaria is related to poverty. It is therefore wishful thinking to expect that good net coverage in the groups who most need it can be reached or maintained by free market processes alone.
**Re-treatment issues**

Re-treatment presents one of the biggest challenges. A major issue that countries have considered is, who does the re-treatment? Can communities do it with minimal support from health workers, and achieve high levels of re-treatment? To a large extent this will depend on the perceived benefit, purchasing power and cohesiveness of the community. However, experience shows that in most situations self-treatment on own initiative and costs doesn’t work to maintain the desired coverage (neither in Africa nor S.E.Asia).

Communities should certainly be involved as much as possible, but there must be a lead organisation to ensure that re-treatment is accessible to the communities and families most at risk, is done at the right time and achieves high coverage and correct dosage.

Methods of re-treatment affect compliance. While group treatment is acceptable for new nets, most families do not like to have their old nets washed and treated with other nets. Strategies that address these community concerns, such as providing buckets to families to retreat their nets privately, are likely to improve rates of re-treatment. (In Vietnam people bring their net in a bowl, bucket or plastic bag of their own.)

Another question is, how do programs record re-treatment rates (whether communities or program staff are doing the re-treatment). Bio-assays with susceptible mosquitoes seem practically impossible for regular operational monitoring. Simple and cheap (non-destructive) biochemical methods would add a valuable indicator (Verle, Ruyen et al. 1998).

The role of newer technologies, such as Permanets that do not require re-treatment, needs to be established but looks promising. A major issue that is brought up with regard to PermaNets or other conventionally pre-treated nets is the value of having the community involved in the treatment and re-treatment processes. Pre-treated and long-lasting nets reduce considerable logistic problems but do communities and individuals maintain a better awareness about the purpose and benefit of using nets by participating in re-treatment activities? Many people feel strongly that this is the case and that therefore pre-treated nets should not be used.

On the other hand, if the resources that would otherwise be needed for re-treatment operations were used to address directly the objective of reinforcing health promotion and community awareness, that might be more effective. This might best be integrated with net-replacement strategies based on intensive coverage checks.

**Net replacement issues**

Is there enough information on average expected life span of different types of nets used in different settings? Probably not. There is no absolute and objective criterion when a net should be replaced for the purpose of malaria control. There is evidence that nets
with large tears and holes are still effective when treated. Therefore, the degree of wear that people tolerate when using the net (or dare to bring it for re-treatment!) is important. Life-span is therefore subjective and will vary substantially between groups and individuals.

Methods that have been tried include swapping old nets for new ones, or simply assuming that nets will last, say, 5 years and beginning a whole new distribution at those intervals. However, a continuous running program that ensures regular and sustained contact with the target groups and in which re-treatment, net replacement and program monitoring activities are combined seems preferable (see also 3.5.6).

There are communities where people after the introduction of ITN have replaced their nets at their own cost. However, in Asia these are in general not the people or groups most at risk of malaria. Here the same argument applies as with re-treatment: in a situation of basic inequity, sole reliance on free market processes often leads to increased inequity. In the case of poverty-related diseases such as malaria, economic forces and realities may play a positive role, but they need to be bounded by laws and strong overarching equity-enhancing mechanisms. The problem remains where the public sector is not strong enough, or unwilling to realize a massive and equitable distribution. In some African countries interesting and well-designed initiatives are going on to make most of forms of social marketing and private-public cooperation. There this may be the only option to realize an ambitious expansion of the use of ITN.

**Revolving funds**

To expect that revolving mechanisms automatically can lead to self-reliance has as a rule led to disappointments, but variants of revolving funds may still be valuable to achieve partial cost-recovery within a strategy that has set conditions of equity and sufficient coverage. Further innovation and experimenting with such mixed systems needs to be encouraged.
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4. CONCLUSIONS

4.1 Human and social factors are prime determinants for ITN application

Achieving high, appropriate and sustained bednet usage in the groups with significant morbidity and mortality is crucial to the success of any insecticide-treated bednet (ITN) program.

In the Pacific and SE Asian region there are \textit{a priori} no epidemiological zones/ “malaria types” or vectors for which ITN would not contribute to malaria control.

Where ITN appear to fail, this is in many cases due to human behaviour factors related to coverage, proper and consistent use of ITN. These human factors are underrated, not systematically monitored, or at least go underreported in many publications and reports.

The dependency on community participation and the problems to change behaviour of people who are difficult to reach can be seen as a disadvantage of ITN as a vector control method. However, exactly ITN programmes have proved very instrumental towards the socialisation of malaria control and community participation. The benefits towards improved health awareness, primary health care and community self-reliance should be taken into account when comparing the cost-benefit of ITN programmes versus alternative vector control options. Besides, where ITN fail due to human factors, the full potential of strategies and approaches for improvement has clearly not been exhausted.

4.2 Barriers to proper ITN usage and scope for improvement

In so far as human behaviour can be considered as the result of a weighing of inconvenience (“cost”) against perceived benefit, it would help to study the problematic situations in these terms to identify which interventions would be most effective to shift the balance towards good net usage.

Among the barriers for proper and consistent use of ITN can be mentioned:

\textit{Objective:}
- Too few nets, or too small, to cover the whole family
- Cost
- Impractical to mount (small houses; in the forest, etc.)
- Inconvenient (stuffy) during hot season
- Incompatible with sleeping around a fire in cold season
- Objections to insecticide use (e.g. families rearing silk worm)
- Hindering certain night time activities (e.g. guarding plots against pigs)
- Hindering mobility in forest activities

\textit{Subjective:}
- Nets were never used before (‘not a habit’)

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- Fear of side effects of the chemical
- Lack of biting nuisance (few mosquitoes)
- Lack of fear for malaria (e.g. in highly immune people)
- Non-belief in the benefit of disease prevention

Lack of (the right type of) nets and cost are naturally addressed in any ITN program, and some programs have successfully supplied blankets next to nets to alleviate the cold season problem. However, the other inconveniences can not be dealt with so easily and the only course of action may be to put more effort in enhancing the (subjective) expectations of benefit (e.g. by social marketing methods).

On the other side of the balance the list likewise starts with some problems that ITN programs have dealt with convincingly. Changing the ‘habit’ towards net use has often been surprisingly easy even in traditional highland communities, once the purpose had been explained and nets were made available. “Surprisingly” here signifies an emotion in health staff and malaria program managers who initially thought it impossible to change habits; the target groups were not surprised at all. Too often our beliefs are prejudices are regarded as absolute truths and we are reluctant to question them. Just trying, or asking people, can change the whole perspective of what is possible or not.

Although by far not everything has been tried yet there is likely to be a point somewhere where the balance can not be tipped by a reasonable amount of effort. To look for possible determinants or indicators of such a contra-indication to the deployment of ITN was the purpose of this discussion.

The most problematic situation is where objective inconveniences are grave and combined with a lack of motivation. This is the case in the ethnic forest workers in Asia. There are no easy technical fixes yet to make it more convenient for them to use nets, except perhaps hammock nets if they use hammocks (many don’t). But by virtue of their immunity they don’t fear malaria and carrying and hanging a hammock as well as a net is still cumbersome. The marketing techniques needed to change the lack of perceived benefit have not been developed yet and we can not be sure in advance that they can be adapted to their culture (value system).

In countries where this situation exists together with sizable populations at risk that can be easily protected by ITN, it is reasonable if country programs make a trade-off and employ their resources to maximize cost-benefit (cost of malaria case or death averted), while the forest workers enjoy and maintain their immunity.

There is a ‘catch’ however where the maintenance of good control in the ‘easy’ areas is continually thwarted, and perhaps diminished, by the continued import of parasites by

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3 The Jarai people in Vietnam traditionally sleep around fires in their house and program staff were afraid that could be a problem for net acceptance. When a woman, after net distribution, was asked how she thought about that matter she replied: “Since I have a net I don’t need the fire anymore to ward off insects – it saves me firewood!” (pers. experience. Marchand)
people who maintain intense transmission in the forest. Unfortunately this seems to be the case in at least Vietnam (relatively well under control) and may soon become the case in the rest of SE Asia. In that case finding a solution for the forest workers serves a greater benefit than just protecting them – and may cost more.

In this case, because we have no solutions or alternatives yet, it is justified to invest more money in research. But multidisciplinary research where the social, economic and epidemiological aspects all have their proper place so that possible technical as well as social solutions can be tested for their effect on malaria epidemiology. And research with a participatory attitude and aim, because without the active involvement of this target group it is impossible to improve their condition.

At end of the day a kind of ‘action research’ may be needed with a broader view than malaria control. These problematic groups are also most ‘out of reach’ for the primary health care system and for general socio-economic development. If and when the communities to which they belong can develop more also in a socio-economic sense, economic opportunities may diversify. Reduced poverty may lessen reliance on the risky forest occupations. Better malaria control will reduce immunity in the children who grow up in the villages and will make the forest work for them later much more risky – increasing the perceived benefit of malaria prevention by personal protection. There can be little doubt that in that case hammocks with nets (as well as the use of repellents) will become more desirable.

*The conclusion would be that there are no groups for which ITN would a priori be useless. But continued studies will be required among the most problematic groups and areas with an open mind for additional protection measures and social innovations.*

4.3 **Towards criteria and guidelines for ITN application**

This review has not detected malarious situations or groups where ITN could never be useful. However, there are situations where ITN may not yet, or not anymore, be indicated. The first is a matter of phasing the expansion and introduction of ITN. But the second can be expected to become more and more important in future, when most populations at risk are covered, the malaria indicator map has changed and a rational resource allocation of re-treatment activities and insecticide is desired to avoid wastage.

These two situations are characterized by quite different conditions and criteria.

ITN may not yet be introduced when, for instance:

- The local health or administrative system is too weak to be relied on for serious health education and community mobilization;
- IEC is not adapted to the local culture;
- An effective strategy for reaching community acceptance, proper use and sustainability has not yet determined by (participatory) social research.
The target population is living so remotely that to reach them would cost a disproportional amount of resources, so that the same resources could prevent more malaria cases elsewhere.

The last situation may for several countries, until recently, have applied. However, with increasing in-country and foreign possibilities for funding this seems hardly justified anymore. In the other cases, mobile teams should at least provide EDAT – training and drugs. Spraying teams can provide IRS as a temporary alternative, provided that IRS is technically possible (suitable substrate of sufficient size).

When in an ITN area malaria incidence has become so low that the cost-benefit (in terms of cost per malaria case averted) seems too low to justify the insecticide and re-treatment costs, programs planners will be tempted to interrupt re-treatment and net replacement. While this is rational, among the criteria for decision-making, careful attention should be paid to the role that ITN may play in outbreak prevention:

- Malaria has decreased under a certain threshold value of malaria indicators;
- Malaria control has been socialized and improved EDAT is in place;
- Vector capacity (human biting and sporozoite rates compared with original situation) has decreased under a certain threshold value;
- An area has a low vulnerability to the import of parasites from more intense endemic areas. (NB: Barrier zones will not help much if there is a sizable movement of human parasite carriers.)
5. PROPOSED STATEMENTS FOR DISCUSSION:

1. In the Pacific and SE Asian region there are \textit{a priori} no epidemiological zones/“malaria types” or vectors for which ITN would not contribute to malaria control.

2. Where ITN appear to fail, this is in many cases due to human behaviour factors related to coverage, proper and consistent use of ITN. These human factors are underrated, not systematically monitored, or at least go underreported in most publications and reports.

3. Within the spectrum of barriers to proper usage of ITN by target populations there is scope for improvement if ITN programs base their IEC activities on participatory sociological study of community needs and perceptions and take time to carefully design and test the most effective messages and channels.

4. The most difficult group to use ITN and derive protection from it are people from ethnic minorities who, by economic necessity or habit, work and sleep in the forests. This group and the communities into which they import parasites will finally benefit from participatory, multidisciplinary research towards behaviour changes and suitable personal protection methods in which ITN (e.g. hammock nets) will play an important role.

5. ITN programmes have proved very instrumental towards the socialisation of malaria control and community participation. In several cases the benefits of this “lynchpin” effect (courtesy of M. Ettling) towards improved primary health care and self-reliance outweigh the benefits of malaria prevention per se.

6. Due to the strong relation between poverty and malaria risk, ITN programmes can not rely solely on free market processes for sustainability.

7. Although the introduction of ITN is most easily implemented by a ‘project approach’, the maintenance will be best through integration in routine programmes in which re-treatment, net-replacement and IEC reinforcement are coordinated and combined. The first step in planning the shift from project to routine operations may be to lobby for sustained (government) funding.

8. **Criteria for phasing the expansion of ITN programs**: if there are no malaria situations where ITN should never be considered, there can be situations where ITN should not YET be used:
   - Non-existent or weak health system;
   - IEC not adapted to local culture;
   - Optimal strategy for reaching community acceptance and proper use not yet determined by (participatory) social research.

In this case mobile teams should at least provide EDAT – training and drugs, and spraying teams can provide IRS as a temporary alternative, provided that IRS is technically possible (suitable substrate of sufficient size).
9. **Criteria for interrupting re-treatment/net replacement:** where ITN programmes are often helpful also in improving socialisation of malaria control and improved EDAT, the situation may improve to such an extent that insecticide treatment could be withdrawn (and used where it is more needed). For taking such decisions, besides the determination of certain threshold values of malaria indicators, attention needs to be paid to the function that ITN may have for outbreak prevention:

- Significantly decreased vector capacity (human biting and sporozoite rates compared);
- Vulnerability to import of parasites from more intense endemic areas. (Barrier zones will not help much if there is a sizable movement of human parasite carriers.)
REFERENCES


