Control of malaria vectors: cost analysis in a province of northern Vietnam

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Summary

The cost of permethrin-treated bednets (50% EC; 0.2 g/m2, 2 rounds per year) was compared to the cost of residual spraying with lambdacyhalothrin 10% WP (0.03 g/m2, once yearly) in Hoa Binh, a mountainous province in northern Vietnam. Calculations of the amounts of insecticides needed were based on national guidelines, on data from a cross-sectional survey and on district activity reports. The actual cost of insecticide required per person per year was lower for impregnation (US$ 0.26) than for spraying (US$ 0.36), but the difference was smaller than expected. The total cost for impregnated bednets per person per year amounted to US$ 0.90 compared to US$ 0.47 for spraying. The determining factor was the cost of the net, amounting to US$ 0.58 per person per year, assuming a 5-year life of the net. Other material (excluding nets), labour and transport combined, accounted for only 17% of the impregnation cost and 23% of spraying expenses. However, for the National Malaria Control Programme of Vietnam, the cost per person per year for impregnated bednets amounted to US$ 0.32 only, because the vast majority of nets are bought by the population. For spraying, the programme had to bear the entire cost.

Keywords malaria, vector control, insecticide-treated bednets, cost analysis, Vietnam

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Introduction

In 1955 the worldwide malaria eradication programme was formally endorsed by the 8th World Health Assembly. The main technique used was spraying of DDT on the inside of house walls (residual spraying), where the vector, Anopheles mosquitoes, rest after they have fed and pick up lethal doses of insecticides. In almost all parts of Asia this resulted in an impressive reduction of malaria prevalence, although malaria could not be eradicated despite expensive and prolonged efforts (WHO 1982; Bruce-Chwatt 1985). The reasons evoked included vector resistance to insecticide, changing mosquito behaviour, inadequate application of insecticides and insufficient resources (Farid 1979; Curtis 1991). In 1969, the World Health Assembly recommended a control strategy with more emphasis on case management. In Asia the overall number of reported cases initially increased, and subsequent declines could not be maintained due to increasingly widespread drug resistance (WHO 1982, 1989). Rising morbidity and mortality due to malaria worldwide resulted in the formulation of a global malaria control strategy considering all available control tools (WHO 1993). New, safe and quick-acting synthetic pyrethroid insecticides created new prospects for vector control (Elliot et al. 1973). Bednets impregnated with pyrethroids rapidly emerged as an effective additional tool for malaria control (Rozendaal 1989; Sexton 1994; Lines 1996), and synthetic pyrethroids became the insecticides of choice for residual spraying (Coosemans & Carnevale 1995).

With two effective vector control methods available, cost should be an important element for deciding which one to use. However, estimations are usually based on theoretical calculations which might be inaccurate. Actual field data of cost of vector control are scarce. We compare theoretical calculations and actual observations on both spraying and impregnation of bednets in Hoa Binh, a mountainous province in northern Vietnam.

Materials and methods

Hoa Binh Province (total population 700,000) consists of 10 districts divided into 211 communes, with about 250,000 people considered at risk for malaria. Each commune has a
The cost per person, total costs were divided by the number of wages and incentives of the studied campaign. To calculate NMCP and did not fund expenses for material transport, costs generally incurred because the Belgian project provided NMCP in Hoa Binh. These costs are representative of the work of a Belgian malaria control project supporting the spraying of all inner wall surfaces up to 2 meters from floor level with lambdacyhalothrin (Icon®, 10% WP, packed in sachets of 62.5 g) at a dose of 30 mg a.i./m² (Ministry of Health 1996). Floors of houses built on stilts should also be sprayed underneath, as they also are resting places for Anopheles mosquitoes (Phan et al. 1980).

In 1996, Imperial® EC was purchased at US$ 30/l and Icon® WP at US$ 70/kg CIF (cost, insurance and sea freight) via Haiphong harbour. Assuming that one double net protects on average 2.5 people, 5.36 ml of Imperial® was required to protect one person for one year by impregnation, corresponding to US$ 0.16. Assuming an average circumference of 75 m and 5 persons per house, 30 m²/person should be sprayed in northern Vietnam if houses are not built on stilts. This corresponds to 9 g of Icon® costing US$ 0.63/person/year (Table 1).

Cross-sectional survey
Overall, 345 households were included, covering 1811 individuals (5.25 people on average per household). Sample households possessed 842 double nets and 151 single nets (assumed to be on average 16.7 m² and 9 m², respectively). 91% of residents always slept under nets. On average, a double net was used by 2 persons so that 6.7 ml/person/year (US$ 0.2) was needed to cover 1 person sleeping under a double net for one year (Table 1). The surface to be sprayed was measured in 345 houses of which 220 (63.8%) were built on stilts. Overall, 24675 m² of wall surface and 14911 m² of floor surface area.
were sprayed (on average 115 m² per house). This corresponded with 22 m² per person/year (US$ 0.46).

**District reports**

Impregnation was carried out in 452 hamlets, each containing on average 75 houses and 400 individuals. Overall 3944 single and 62,326 double nets were impregnated at a target dose of 0.2 g a.i./m², corresponding to 71% of the total population covered with insecticide-treated bednets during the first round of 1996. Actually 536 l (estimated average of 0.26 g a.i./m²) of Imperator® were used compared to 432 l theoretically required for this number of nets according to the national guidelines. This amounted to US$ 0.13 per person for protection during this round, ranging from US$ 0.10 to US$ 0.14/person for the different districts (based on 1 person/single and 2 persons/double net). For cost of protection during one year these figures should be doubled (Table 1).

More than 98% of 5183 houses were sprayed in 70 hamlets (26 748 persons reportedly protected), using 136.5 kg of Icon®. On average 26 g per household or 5.1 g per person was used. However, this differed significantly from one district to another, ranging from 14 to 59 g per household (US$ 0.19–0.83 per person). Variables explaining these important differences were surface covered, speed of application and pressure of the spray tanks. With available data it was impossible to analyse the quality of coverage; only the average amount of insecticide used per house could be calculated.

**Other costs**

Actual total cost and cost to protect one person for one year by both methods of vector control in Hoa Binh are presented in Table 2. Impregnation equipment consisted of nets, gloves, masks and bowls. Nets were by far the most expensive items. The users purchased most nets themselves. The retail cost of a double polyester net, the most expensive, was about US$ 5, in remote communes as well as in the city. These are assumed to last 5 years, thus costing US$ 0.58/person/year. The factory price in Hanoi for large quantities was about US$ 3.8. Machine-manufactured cotton nets were about US$ 0.5 cheaper but less durable (assumed to last 3 years). In 1996, 2000 double cotton nets were purchased with funds of the NMCP, but these represented only a fraction of all nets in the Province. The cost/person/year (0.61 US$) of these programme-provided nets is about the same as for the polyester ones. Traditional nets of cheap heavy cotton made by the villagers themselves last longer and should be cheaper. The cost of gloves and masks (< 0.7 US$/set) per protected person per year was negligible.

Apart from the nets household costs for both impregnation and spraying are minimal. Impregnation sessions are spread out over the day and waiting times are limited. Often children bring the nets, so that adults do not have to interrupt their activities. The bowls used for impregnation twice a year were purchased for other household purposes and therefore their cost was not taken into account in this study. If a house is unlocked, it is sprayed in the presence of hamlet authorities even if the residents are absent.

Spraying equipment has been described and recommended by the WHO (1990). Prices of hand compression sprayers range from US$ 130–550. In 1996, each district of Hoa Binh disposed of 2 spray tanks of the most expensive kind (including spare nozzles), which are expected to last for more than a decade if maintenance is assured. In 1996 one spray tank was used to spray more than 260 houses/year, corresponding to a cost of 0.05 US$/person/year for pumps.

Impregnation sessions involve the participation, on average, 2 staff members from district or province level. All nets of an average-sized hamlet (75 households) can be impregnated in one day. Often the villagers themselves perform the impregnation. Clear instructions in Vietnamese are available, and the role of specialized staff is primarily supervision and motivation. Spraying, on the other hand, is a skilled task and...
does require specialized staff. In the mountainous areas of Hoa Binh, considered at higher risk for malaria, spraying of an average hamlet required 5 man-days. In Table 2, labour costs were calculated based on average wages and incentives paid (3.5 US$/man-day).

Currently fuel (US$ 0.25/l) and maintenance of vehicles and motorcycles are cheap in Vietnam. For both methods, equipment and material needed for one hamlet can be transported by staff doing the application. In Table 2, transport costs were calculated based on invoices and divided by the number of hamlets covered per method. Transport of nets bought by individuals was included in the retail price.

**Table 2** Actual cost per person covered per year with insecticide treated bednets (permethrin 0.2 g a.i./m², 2 x/year) and with house spraying (lambdachlorothrin 0.03 g a.i./m², 1 x/year) in Hoa Binh province, Vietnam, in 1996 (1US$ = 11 000 Vietnamese Dong)

<table>
<thead>
<tr>
<th>Hamlets covered</th>
<th>Insecticide treated nets</th>
<th>Spraying</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population covered</td>
<td>128 596</td>
<td>26 748</td>
</tr>
<tr>
<td>Treatment costs</td>
<td>US$</td>
<td>US$</td>
</tr>
<tr>
<td>Insecticides</td>
<td>33 360 (69.6%)</td>
<td>95 355 (76.6%)</td>
</tr>
<tr>
<td>Equipment &amp; material</td>
<td></td>
<td></td>
</tr>
<tr>
<td>sprays</td>
<td>–</td>
<td>14 25 (11.4%)</td>
</tr>
<tr>
<td>gloves – masks – bowls</td>
<td>125 (0.3%)</td>
<td>20 (0.2%)</td>
</tr>
<tr>
<td>Labour at 3.5 US$/man-day</td>
<td>6 328 (13.2%)</td>
<td>1 225 (9.8%)</td>
</tr>
<tr>
<td>Transport</td>
<td></td>
<td></td>
</tr>
<tr>
<td>insecticide to district</td>
<td>300 (0.6%)</td>
<td>50 (0.4%)</td>
</tr>
<tr>
<td>local</td>
<td>1 200 (2.5%)</td>
<td>200 (1.6%)</td>
</tr>
<tr>
<td>Total treatment cost</td>
<td>41 313</td>
<td>1 2475</td>
</tr>
<tr>
<td>Nets provided by the programme</td>
<td>6 600 (13.8%)</td>
<td>–</td>
</tr>
<tr>
<td>Total programme cost</td>
<td>47 913 (100%)</td>
<td>1 2475 (100%)</td>
</tr>
<tr>
<td>Programme cost for treatment/person</td>
<td>0.32 US$</td>
<td>0.47 US$</td>
</tr>
<tr>
<td>Annual cost per net</td>
<td></td>
<td></td>
</tr>
<tr>
<td>user purchase of net/year</td>
<td>0.58 US$</td>
<td>–</td>
</tr>
<tr>
<td>(1 net of US$ 5/pers/5y – 5% discount)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>net provided by the programme</td>
<td>0.61 US$</td>
<td>–</td>
</tr>
<tr>
<td>(1 net of US$ 3.3/pers/3y – 5% discount)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total cost/covered/person/y</td>
<td>net purchased by user</td>
<td>0.90 US$</td>
</tr>
<tr>
<td>net received from the programme</td>
<td>0.93 US$</td>
<td>0.93 US$</td>
</tr>
</tbody>
</table>

(a) US$ 30 × 11 112 l permethrin and US$ 70 × 136.5 l lambdachlorothrin; (b) 20 pumps of 550 US$/10 years, 5% discount; (c) salary + allowance: 2 × 2 man-days/hamlet for impregnation, 1 × 5 man-days/hamlet for spraying; (d) 2 000 nets × US$ 3.3.

It is not surprising that more insecticide than planned (30% surplus) was used for impregnation. Traditional bednets (up to 25% in some districts) are not standardized (neither for size nor for material) but are always much bigger than commercial nets and absorb much more water. To assure minimum dose, staff were advised to double the quantity of permethrin to impregnate traditional nets. Also, with individual dipping of bednets, spillage of insecticide for impregnation easily occurs. Nevertheless, insecticide cost per person for impregnation varied little between districts.

Since the insecticide for spraying is supplied in packets containing the exact quantity of product (62.5 g Icon®) needed for one spray tank, spillage is less likely. In some districts almost one spray tank was used per house. Higher averages were reported in districts with the poorest accessibility, which tend to have large houses built on stilts with spacious verandas. The verandas are also sprayed since they can be resting places for malaria vectors (Phan et al. 1980). In three of 10 districts, insecticide for spraying was cheaper per person protected than insecticide for impregnation. The lowest insecticide cost for spraying was found in the district of the provincial capital. This is because in town,

**Discussion**

Our study reveals the importance of comparing estimated and actual cost. Cross-sectional surveys may explain to some extent the reasons for differences observed between actual and anticipated expenditure based on national guidelines. Data based on district reports confirmed that the average cost of insecticide required to cover one person for one year is lower for bednet impregnation (two rounds per year) than for spraying once yearly (Table 1, Figure 1). However, insecticide cost for impregnation was higher and for spraying it was lower than expected compared to estimates derived from national guidelines.
the houses are small and closely packed.

With more than 90% of the population using bednets, it is justified for the NMCP to encourage bednet impregnation rather than spraying in Hoa Binh. The NMCP bears almost the entire cost of spraying. For protection by insecticide-treated bednets, the net – the main cost – is paid by the population. So, despite an overall higher cost, more people can be covered with impregnation by the programme. However, these calculations are based on the assumption of a five-year life per net. In the literature, figures vary from 2 to 6 years, but information is limited (Feilden 1996). During a field trip in Hoa Binh we were shown a net used for over 32 years. Obviously a longer net life would make a lot of difference. Similar cost to indoor spraying would be obtained with nets costing US$2 or 5 per piece and lasting 5 and 15 years, respectively (Figure 1). To obtain more reliable data, questions about net life should be included in cross-sectional surveys of communities such as Hoa Binh, where net use has been stable for a long time.

If net costs are not considered, insecticide costs are the determining factor. Other equipment and material, labour and local transport combined was only 17% of impregnation and 23% of spraying cost. The cost of insecticide would have to increase by 120% in order to obtain equivalent costs between spraying and impregnation of nets (Figure 1). In the present project, insecticide cost is stable since a contract with the supplier guarantees the same CIF price from 1995 until 1999. Such contracts also have the advantage of reducing management costs and the risk of delayed supply, mainly when insecticides are sea freighted. However, foreign exchange fluctuations alone can influence cost per person enormously because insecticides are imported. In Vietnam the exchange rate changed from 1 US$ = 11 000 Vietnamese Dong in 1996 to 1 US$ = 14 000 Vietnamese Dong by the
middle of 1998. The choice of an insecticide also has important implications for the cost of activities in terms of transport, spraying, storage and safety precautions (Phillips & Mills 1991). By using insecticides supplied in sachets instead of in bulk, manpower for weighing is saved. At the time of DDT spraying in Vietnam, transport alone amounted to 30% of total expenditures (T.D. Hinh, personal communication). This has decreased because of the lower volume of insecticides, higher insecticide cost per volume unit and higher population coverage, consequently lowering the fixed costs per person. More persistent insecticide for treated nets (e.g. lambdacyhalothrin, deltamethrin) may be advantageous, as only one dip a year may be required unless nets are frequently washed (Feilden 1996). At a dose of 10 mg a.i./m², an annual dip with lambdacyhalothrin, assuming US$ 60 for 1 l EC 2%, would cost the same as two dips a year with permethrin 50% EC at 0.2 g a.i./m² (Figure 1).

For both methods, the observed costs per person in this study correspond to the lowest ones found in other studies (Wéry & Coosemans 1993; Feilden 1996), mainly due to low labour and local transport cost. Few studies compared the costs of both intervention methods. In Burundi insecticide-treated nets cost about the same as indoor spraying unless fewer than 10 houses were sprayed per man per day. In the Solomon islands, Kere & Kere (1992) estimated that insecticide-treated nets were about 50% cheaper than spraying with DDT, but their analysis compared two DDT spray rounds per year with only one permethrin dipping session per year.

Vector control guidelines of national malaria control programmes should be based on more than cost alone. In expressing the results in terms of cost per person protected, it is assumed implicitly that both control methods are equally effective. However, insecticide-treated nets will be more effective on an exophilic vector than indoor spraying. This may be the case in northern Vietnam, where two sympatric A. minimus have been identified: an endophilic and an exophilic species (Van Bortel et al. in preparation). Furthermore, acceptability and feasibility are essential. Sustainability should be considered. Several pyrethroid insecticides and formulations are available and applied at different doses. However, remarkably little attention has been given to comparative trials to determine which are most cost-effective (Curtis et al. 1996). In the last decade many efficacy studies were conducted, but cost-effectiveness data are still limited. Finally, the decision of using vector control should be considered in the framework of the general health policy.

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