Cost of malaria control in Sri Lanka

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The study provides estimates of the cost of various malaria control measures in an area of North-Central Province of Sri Lanka where the disease is endemic. We assumed that each measure was equally effective. In these terms, impregnating privately purchased bednets with insecticide was estimated to cost Rs 48 (US$ 0.87) per individual protected per year, less than half the cost of spraying houses with residual insecticides. Larviciding of vector breeding sites and especially the elimination of breeding habitats by flushing streams through seasonal release of water from upstream reservoirs was estimated to be cheaper than other preventive measures (Rs 27 (US$ 0.49) and Rs 13 (US$ 0.24) per individual protected, respectively). Inclusion of both operational and capital costs of treatment indicates that the most cost-effective intervention for the government was a centrally located hospital with a relatively large catchment area (Rs 71 (US$ 1.29) per malaria case treated). Mobile clinics (Rs 153 (US$ 2.78) per malaria case treated) and a village treatment centre (Rs 112 (US$ 2.04)) per malaria case treated) were more expensive options for the government, but were considerably cheaper for households than the traditional hospital facilities. This information can guide health planners and government decision-makers in choosing the most appropriate combination of curative and preventive measures to control malaria. However, the option that is cheapest for the government may not be so for the householders, and further studies are needed to estimate the effectiveness of the various preventive measures.

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Introduction

A large proportion of Sri Lanka's health budget is spent on malaria control. The most recent year for which a central figure is available is 1989, prior to the devolution of the health budgets to the provinces. At that time 11.6% of the total budget was spent on all forms of antimalaria activities nationwide, including both malarious and nonmalarious parts of the country (*1*). In 1992, it was estimated that 36% of the total health expenditure in a malaria-endemic district of the country was used to combat the disease (*2*). The cost to the government of antimalarial activities relates mainly to vector control, e.g. spraying houses with insecticides and larviciding vector breeding habitats, supporting diagnostic and treatment facilities, and maintaining an information system. The bulk of malaria control expenditure is currently used on importing insecticides. However, since the implementation of a selective spraying programme in 1994 the total amount of insecticides used has declined significantly (*1*).

Discussion of the most cost-effective use of the budget allocation for antimalaria activities in Sri Lanka requires comparison of the cost-effectiveness of a range of preventive and curative interventions. This comparison needs to be based on standardized cost estimate procedures and comparable units of effective outputs. Furthermore, to be able to discuss the most suitable interventions, we need to include the cost to households and not only the cost estimates borne by government agencies.

In Sri Lanka, the transmission of malaria exhibits considerable seasonal and annual changes, the population is highly knowledgeable about the disease, the majority of the cases are caused by *Plasmodium vivax*, and the health facilities provide relatively good coverage. All of these make it very difficult to compare health intervention strategies in Sri Lanka with cost-effectiveness studies carried out in Africa. To the best of our knowledge the only studies of the cost of malaria control to the government in Sri Lanka are those by Attanayake (*2*) and Graves et al. (*1*). The present study includes a number of additional interventions not dealt with by these two previous studies, such as water manage-

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ment for vector control and a village-level treatment centre.

The cost estimates were generated from data for a rural area in the malaria-endemic part of Sri Lanka, where ongoing research activities made it possible to estimate the cost to the government and households of both traditional and novel malaria control interventions. Results from epidemiological studies and surveys of treatment-seeking behaviour undertaken among the study population were used to assess the most appropriate interventions for the area.

Materials and methods

Study area

The study was carried out in Anuradhapura District, in the North-Central Province of Sri Lanka, in an area covered by seven neighbouring villages, consisting of 512 households and a total population of 2575 (average household size, 5 persons). The office of the Anti-Malaria Campaign (AMC) in Anuradhapura is headed by a regional malaria officer (RMO) who undertakes entomological surveillance and special surveys and provides advice to the divisional director of health services, the public health inspectors, and other personnel responsible for malaria control activities within the district. The majority of the households are engaged in agriculture, primarily subsistence farming.

In 1995, a survey in the study area showed that 48% of malaria patients first sought treatment at the government hospital in Kekirawa, approximately 25 km from the cluster of study villages; 30% used the government managed mobile clinics; and the remaining 22% private or other Western-style facilities (*3*). In fact, a number of patients attended both the mobile clinics and hospital. The community had a good understanding of the transmission route of malaria and the drugs required for its treatment, and placed great importance on positive blood-slide confirmation before treatment.

Data collection

The cost estimates and the epidemiological background information were collected for the period 1 October 1994 to 30 September 1995. A review of the health statistics for the Kekirawa division over the period 1979 to 1995 shows that the level of malaria transmission in 1994–95 was average *(4)*.

Data on salaries and travel allowances, staff input, cost of fuel, chemicals and other supplies, and the amount of chemicals required for each intervention were provided by various branches of the Ministry of Health, including the AMC. In addition to weekends and national holidays, two days per month were added to the cost of labour input to cover the expenses related to sick leave and personal holidays. This additional cost was averaged over a month and added to the daily salary rates. Chemicals are currently purchased by the AMC and transported to Anuradhapura town for storage. The cost of transport and storage was added to the import price of the chemicals. The cost of chemicals was based on the standard formulations used by the AMC. The cost of capital investment was derived from actual expenditures recorded by the Ministry of Health; full depreciation was assumed after 7 years for vehicles and 20 years for buildings. Maintenance expenses were also included.

Although the data needed for analysis of the different malaria control interventions have been taken to be representative for the whole area covered by the regional office of the AMC in Anuradhapura District, they have only been exemplified and validated for the study area.

On the basis of data collected as part of a previous survey in the study area, we were able to estimate the cost to the households of seeking treatment at the various facilities (*3*). The number of blood slides examined and cases treated by the government mobile clinic and at one of the main facilities (Kekirawa hospital) servicing the study area were obtained from the AMC and the registrar of the malaria unit of the hospital, respectively. Cost estimates for the village-based treatment centre were obtained from the reports of ongoing research activities in the study area.

In order to compare different preventive and curative interventions, we devised common units of measurement. For curative interventions two units were used: the cost per blood slide examined by a microscopist, and cost per blood slide found to be malaria positive and treated. For preventive interventions, the unit was taken to be the cost to protect a person for a year or for a season. For all interventions, both operating and fixed costs to the government and households were calculated. Some interventions required a vehicle when the activities were carried out or for supervisory purposes, adding considerably to the capital costs. The fixed cost of the hospital was based on current replacement value and was annualized based on the approach described by Phillips et al. (*5*), while the fixed cost of the treatment centre was taken to be the rent of the building.

Residual spraying

A spraying team from the health authority in Kekirawa town visited the study area routinely and treated all sprayable surfaces of 25 dwellings per day. The records showed that more houses than this were visited per day but due to householders' absences and refusals only 25 houses were treated. The team included four spray machine operators and one field assistant, who were all paid a salary and travel allowance. The cost of the spraying operations was based on the inputs needed for a "walking unit" (actually making use of a bicycle), with a vehicle only being used for supervisory purposes. The operational and capital costs of the supervision were based on the assumption that a public health inspector with a driver could supervise four walking units per day. Recently the insecticide had been changed from malathion to lambda-cyhalothrin or fenitrothion, and it was assumed that the mosquito vectors had still not developed resistance to these newly introduced chemicals. Fenitrothion was sprayed three times a year and lambda-cyhalothrin twice a year. Fenitrothion costs Rs 404 (US$ 7.35) per kg and approximately 0.50 kg was required for each house. Lambda-cyhalothrin costs Rs 3870 (US$ 70.36) per kg, but only 0.06 kg was required for each house. In areas where malathion was still used it was sprayed three times a year (0.90 kg per house) at a cost of Rs 153 (US$ 2.78) per kg. Household spraying with malathion had a very high acceptance level in the study area, with more than 90% of the houses being treated (*3*). This acceptance was expected to remain high following the introduction of the newer insecticides, since they stain the walls less and are nearly odourless. The annual cost of protective clothing and of other equipment for spraying was Rs 2380 (US$ 43.27). The cost of routine check-ups for the spray operators, using the cholinesterase test, was Rs 2500 (US$ 45.45) per person with check-ups being carried out every 2.5 months.

Bednet impregnation

The government health services supported a mosquito bednet impregnation programme, in which a public health inspector, a field assistant, a driver and a labourer visited an area to dip the nets in a solution of permethrin. This insecticide costs Rs 1120 (US$ 20.36) per litre, which is sufficient for about 20 bednets. The procedure was to impregnate approximately 100 bednets or about 50 households (assuming two double bednets per household) per day. These limits arose because villagers brought their nets to the location where the impregnation was to take place. Also, the efficiency of the impregnation programme depended on the presence of a large proportion of bednet users among the community. At the time of the study, 7% of the households in the study area owned at least one privately purchased mosquito net (cost, ca. Rs 600 (US$ 10.91) for a double net).

Larviciding

The primary vector of malaria in Sri Lanka, *Anopheles culicifacies*, mainly breeds in streams and stream-bed pools. It has therefore been the practice of the AMC to apply larvicides to streams running close to human settlements during the dry period when the water levels in the rivers and streams are falling. One stream (the Yan Oya) that crosses the study area was found to be the only breeding site for *A. culicifacies* during the period mid-June to early September (*6*). To apply the larvicides, a walking unit consisting of a team of spray machine operators and a field assistant from the health department in Kekirawa visited the area and sprayed pools along an average of 1 km of stream-bed per day. A public health inspector, with a driver, supervised the walking unit every fourth working day. Assuming that mosquito breeding in the stream could have an impact on the households living within 1.5 km of the stream, it would take one day to protect an average of 56 households along its banks within the study area. The larvicide used was temephos (cost, Rs 753 (US$ 13.69) per litre), with ca. 0.4 litres being consumed over a 1-km stretch. To effectively protect this area for the 10-week peak stream-bed breeding period, approximately four site visits were required.

Water management for larvae control

The Yan Oya stream is used as a conveyance canal for irrigation water from an upstream to a downstream reservoir, a distance of approximately 25 km. As part of the ongoing research in the area, management of the water releases was an effective means of eliminating the breeding of *A. culicifacies* during the period mid-June to early September (*7*). The water management procedure for mosquito control relied on the release from the upstream reservoir of 22 000 m^3 water every tenth day over a 2-day period. This was expected to reduce formation of pools in the stream and flush existing pools, thereby disturbing the breeding of the larvae present in the stream at the beginning of the tenth day of water release. Thus the flush was required about six times during the 10-week peak breeding season.

Since the water released from upstream is captured downstream, the only water lost to the system is the increased conveyance loss due to the periodic releases into the dry stream. This was estimated at 10% by a water balance study (International Irrigation Management Institute, unpublished data, 1998). The estimated value of water in paddy production in the general study area is Rs 3 (US$ 0.06) per m^3 (*8*), based on the standardized gross value of rice produced divided by the quantity of water diverted to the field. Thus the value of the water lost through conveyance was estimated to be Rs 6600 (US$ 120.00) per control intervention. A farmer under the supervision of an Irrigation Department official regulated the gate at the upstream reservoir. However the cost of this management input is negligible when it is divided by all the households protected (Rs 0.40 per household per intervention). As a result of this flushing, an estimated 600 households would be protected along this 25-km stretch of the Yan Oya stream.

Diagnosis and treatment at the government hospital, Kekirawa

The government hospital in Kekirawa is one of several centres for diagnosis and treatment of malaria within the Kekirawa division (population ca. 45 000). A microscopist and a field assistant attended to patients all days of the week from 09:00 to 16:00, except on Sundays and national holidays. Thus the service was available for about 290 days a year. Positive cases were treated with a standard course of chloroquine (CQ) and primaquine (PQ), and for suspected resistant cases pyrimethamine + sulfadoxine was prescribed (at a cost of approximately Rs 60 (US$ 1.09) per case treated).

However, for our analysis each positive case of malaria was assumed to have been given only CQ and PQ at an average dose of six CQ tablets (a total of Rs 4 (US$ 0.07)) and six PQ tablets (a total of Rs 2 (US$ 0.04)) per case. A new lancet and glass slide were used for each blood sample at a total cost of Rs 4 (US$ 0.07) per patient. During the 1994–95 study period, 10 769 blood slides were examined, 2607 of which were positive (slide positivity = 24%); this corresponds, on average, to 37 blood slides per day.

In addition to staff and other operating costs, the fixed costs of the hospital were calculated at a standard rate of Rs 8070 (US$ 146.72) per m^2. The malaria unit at Kekirawa hospital occupies ca. 28 m^2. This corresponds to a total capital cost of Rs 225 960 (US$ 4108.36), which annualized over 20 years using a real discount rate of 6% and assuming 290 working days a year is equivalent to Rs 68 (US$ 1.24) per day. The capital cost of a microscope (Rs 267 000) was annualized over 15 years, which is equivalent to Rs 94 (US$ 1.71) per day. Maintenance costs of the hospital were assumed to be 10% of capital costs at Rs 7 (US$ 0.13) per day, and have been included in the operating cost figures.

Mobile clinics for the diagnosis and treatment of malaria

During the main transmission periods, the government health service operated specialized mobile clinics. Over the one year study period the study area was visited 20 times, mainly during the months when malaria transmission was high. Patients received the same service at these clinics as they did at the government facility, but the distance they had to travel was shorter, with a maximum distance of 7 km and with ca. 60% of the population living within 2 km of these clinics. Since the mobile clinic visited the area on fixed days of the month, no special promotional efforts were carried out to support the service. The clinic staff included a microscopist, field assistant and driver, all of whom received wages and a travel allowance. As with the hospital, it was assumed that on average each positive case received six CQ tablets and six PQ tablets. During the 1994–95 study period, 1009 blood-slides were examined and 275 positive cases identified during the 20 visits. This corresponds to an average daily total of 50 blood slides and an average of 14 positives per day.

A fixed cost for the type of vehicle used by the mobile team was calculated at Rs 1.3 million (US$ 23 636.36). Spread over 7 years, annualized using a discount rate of 6% and assuming 290 days of use per year, this amounts to Rs 803 (US$ 14.6) per day. Maintenance costs were calculated at Rs 1500 (US$ 27.27) per month, and assuming 290 days of use per year amounts to Rs 62 (US$ 1.13) per day. These maintenance expenses were included in the operating cost figures.

Village level diagnosis and treatment centre

A diagnosis and treatment centre was established in May 1996 in a rented room in the local post office in a village located in the centre of the study area. Secondary school graduates from the study area received a total of 16 days' training at the Universities of Colombo and Peradeniya in the management of a village health facility, mainly focusing on blood slide examination and record keeping. This was followed by on-the-job training by a university graduate located in the study area and by AMC staff. Following the establishment of the centre the existing staff trained new assistants. The trained assistants were paid a daily salary slightly below the level of a field assistant in the government service, but received no field allowance. The centre was staffed by two assistants every day during its opening hours from 08:00 to 16:00. For our analysis, the start-up expenses and the initial promotional work (i.e. training, initial supervision, poster campaign, and community meetings) were not included in the cost estimate. The diagnostic procedures and the drug regimen at the village level centre were equivalent to those at the government facility in Kekirawa and the mobile clinics. To maintain the quality of work, two half-day supervisory visits were made every month by staff of the government health service. After the village treatment centre was opened, the mobile clinics no longer visited the study area. A survey carried out on 90% of the households in the study area showed that 74% of the patients with suspected malaria first attended the village treatment centre, with the government hospital in Kekirawa being the second choice (International Irrigation Management Institute, unpublished data, 1998). To assess the cost per blood slide examined and per case treated for the same period as that used for the government hospital and the mobile clinics, we used detailed epidemiological data collected in one of the seven study villages (*9*). In this village over the period October 1994 to September 1995 each person had an average of 0.8 episodes of malaria. Had the village treatment centre been up and running during this period, and with 74% of the patients seeking treatment at it, 1524 malaria patients would have been diagnosed and treated among the population of 2575. The centre is open 305 days a year and would therefore have seen five positive cases per day. We assumed that the village treatment centre had a slide positivity rate similar to that of the government hospital (24%), equivalent to 20 blood films per day.

The fixed cost of the building occupied by the village centre was estimated to be Rs 20 (US$ 0.36) per day, based on a rent of Rs 500 (US$ 9.09) per month.

Results

Prevention

The residual spraying programme was the most expensive preventive intervention, with fenitrothion being considerably more so than malathion (Table 1). The insecticide was by far the most costly component of the spraying programme, amounting to 75% of the

Table 1. **Operating and capital costs to the government of various antimalaria preventive interventions**

Intervention	Operating cost per day (in Rs)	No. of households protected per day	Operating cost per household per intervention day (in Rs)	No. of interventions per year needed for protection	Annual operating cost per household (in Rs)	Annual capital cost per household (in Rs)	Total annual cost per individual protected (in Rs)
Spraying							
Fenitrothion	6 412	25	256	3	768 (13.96)[a]	24 (0.44)	158 (2.87)
Lambda-cyhalothrin	7 409	25	296	2	592 (10.70)	16 (0.29)	122 (2.21)
Malathion	4 613	25	185	3	555 (10.09)	24 (0.44)	116 (2.11)
Bednet impregnation (permethrin)	5 244	50	105	2	210 (3.82)	32 (0.58)	48 (0.87)
Larviciding[b] (temephos)	1 652	56	30	4	120 (2.18)	16 (0.29)	27 (0.49)
Water management[b]	6 600	600	11	6	66 (1.20)	0 (0)	13 (0.24)

[a] Figures in parentheses are US$ (US$ 1 = Rs 55).

[b] Interventions with only seasonal applicability.

total operating expenditure. Impregnated bednets were considerably cheaper for the government (ca. US$ 0.87 per individual protected per year), less than one half the cost of protecting an individual through residual spraying. If we assume that three and not two bednets are needed per household, the cost to the government per individual protected per year increases to US$ 1.27, which is still substantially less than the cost of the residual spraying programme.

However, to the government cost of impregnating bednets should be added the cost to the households of purchasing the bednets. If it is assumed that two bednets are required per household, the cost would be Rs 50 (US$ 0.91) or Rs 70 (US$ 1.27) per individual protected per year, depending on whether the life span of the bednet was estimated at 6 years or 4 years. Nevertheless, the total cost to the government and households combined made impregnated bednets more cost-effective than the residual spraying programme. Only if the estimates are based on use of three double bednets per household and the nets last 4 years does the combined government and household cost of the impregnation programme make this intervention slightly more expensive per individual protected (at US$ 2.90) than that of the residual spraying programme.

The two cheapest preventive options were larviciding and water management, but it is unclear whether the protection they afforded was comparable to the above approaches, and estimates of their effectiveness were difficult to make. Also, they were appropriate for use only for approximately the 3-month period when the main vector *A. culicifacies* breeds in the streams close to human habitation. However, by interrupting the majority of the breeding early in the transmission season, vector abundance in the succeeding months would be reduced. In streams where water can be managed using existing structures, the use of controlled flushing would provide protection at around half the cost of the use of chemical larvicides.

Treatment

The village treatment centre had a smaller catchment area than Kekirawa hospital, and therefore examined fewer blood slides per day. The mobile clinic had the same catchment area as the village treatment centre, but was functional only during the high transmission season, while the village treatment centre was open all year around. This meant that more blood slides were taken per day when the mobile clinic was in operation compared with the village treatment centre. When the mobile clinic was not in operation as a malaria unit it was assumed that the vehicle and staff were employed elsewhere and, except for the microscopist, were not necessarily involved in malaria control activities. Thus, based on operating cost, the village treatment centre and mobile clinic were more expensive than the hospital (Table 2).

Table 3 shows the cost estimates to the government for curative interventions, including both operational and capital costs, as well as household expenses related to seeking treatment. In the household survey carried out in 1995, a total of 85 households reported a recent malaria episode for which they sought treatment at the hospital. These households incurred a median cost of Rs 55

Table 2. **Operating costs to the government of different curative interventions**

Intervention	Operating cost per day (in Rs)	Average number of blood-films per day	Average number of positive blood-films per day	Operating cost per blood-film examined (in Rs)	Operating cost per positive blood-film (in Rs)
Hospital	483 (8.78)[a]	37	9	13 (0.24)	53 (0.98)
Mobile clinic	1 242 (22.58)	50	14	25 (0.45)	89 (1.61)
Village level treatment centre	443 (8.05)	20	5	22 (0.40)	89 (1.61)

[a] Figures in parentheses are US$ (US$ 1 = Rs 55).

(interquartile range, Rs 35–78) on transport and on food while the patient and the accompanying persons were awaiting diagnosis and treatment. The 54 households that sought treatment at the mobile clinic spent much less (median, Rs 0; interquartile range, Rs 0–10). The survey of the household costs was conducted before the village treatment centre was established, but it is assumed that households attending the centre would spent the same amount as those attending the mobile clinic. Inclusion of the household costs alters the findings, with the village treatment centre being the cheapest option and the mobile clinic the most expensive at Rs 153 (US$ 2.78) per positive case treated, followed by the hospital at Rs 126 (US$ 2.11) for the same output.

However, with possible errors in the estimates, it is probable that, after including the cost to the households, the three curative interventions become comparable in cost. A focus on the centralized treatment facility with a large catchment area is a cheap option for the government but shifts a large part of the expense to the households.

Estimation of the cost of the three curative services depends largely on the average number of cases registered at the facilities. Therefore, to produce a rough sensitivity test for the estimates generated in Table 3, we increased and decreased by 25% the average number of positive cases treated at the three facilities in the calculation. Based on the revised case load at the three facilities, the total cost to the government was estimated to be US$ 1.04–1.72 per positive case treated at the hospital, US$ 2.25–3.62 per case treated at mobile clinics, and US$ 1.65–2.63 per case at the village treatment centre. This shows that, even with the most expensive estimate for the government hospital and the least expensive for the two other treatment alternatives, the hospital was still, from a government perspective, cheaper or approximately the same cost as the two alternatives.

An important item for both preventive and curative interventions was the capital cost of the vehicle. In tests of the sensitivity of the final estimation for the preventive interventions, the cost per individual protected per year increased by a maximum of 7.5% for the bednet impregnation programme when the lifetime of the car was reduced from 7 years to 4 years. For all other preventive interventions the cost increased by less than 2.5%. The total cost estimated per positive case treated for the mobile clinic increased by 19% when the lifetime of the vehicle was reduced to 4 years, making this curative service even less competitive. The cost estimate for the village treatment centre changed only marginally, and that for the government hospital remained the same when the lifetime of the car was reduced. We were unable to obtain any reliable estimates of input wastage for items such as insecticides and drugs. For the residual spraying

Table 3. **Operating and capital costs to government and households of various treatment interventions**

Intervention	Operating cost per positive case (in Rs)	Capital cost per day (in Rs)	Capital cost per positive case (in Rs)	Cost to government per positive case (in Rs)	Cost to household per positive case (in Rs)	Total cost per positive case for both government and household (in Rs)
Hospital	53	162 (2.95)[a]	18 (0.32)	71 (1.29)	55[b] (1.00)	126 (2.11)
Mobile clinic	89	897 (16.3)	64 (1.16)	153 (2.78)	0	153 (2.78)
Village level treatment centre	89	114 (2.07)	23 (0.42)	112 (2.04)	0	112 (2.04)

[a] Figures in parentheses are US$ (US$ 1 = Rs 55).

[b] Median direct cost for the patient from the study area and, possibly, a guardian to seek treatment at the government hospital.

activities especially, this may have important implications; for example, if insecticide wastage were 25%, the costs of spraying would increase by 20%.

Discussion

Seen from the government perspective, a centrally located hospital with a relatively large catchment area is the most cost-effective way of treating malaria patients, while the widespread use of mobile clinics and village facilities is an expensive control strategy. For larval control, the use of designated water management strategies should be explored since this option is far cheaper than the use of chemically based larvicides. For the reduction of bites by adult mosquitos, a programme of impregnating privately purchased mosquito bednets would provide protection to the households at approximately half the price of a residual spraying programme. The residual spraying programme has become more expensive in Sri Lanka because the mosquito vectors have developed resistance to the insecticides and each of the newly introduced insecticides is more costly than its predecessor. In general, the spraying operations in Sri Lanka are not very costly due to the low capital investments in, for example, vehicles. However, this may not be a realistic option in other developing countries with a less developed infrastructure and a low population density.

The assessment of the number of patients seeking treatment at any one of the three facilities in the present analysis was a best estimation and is likely to vary considerably over time. For example, the number of patients visiting the government hospital may vary according to the number of mobile clinics operating in its catchment area and influence the average number of slides taken per day. We therefore assessed the sensitivity of the final cost estimation for the curative interventions by changing the average number of slides taken per day. The results showed that even with a substantial reduction in the number of positive cases treated at the government hospital it was still a cost-effective option from a government perspective compared with the two alternatives.

The cost per case treated by the mobile clinics (Rs 153, US$ 2.78) is well below the Rs 500 (US$ 9.09) reported previously for four districts in Sri Lanka (*1*). Our analysis indicates that the cost-effectiveness of the mobile clinics is largely influenced by the life span of the vehicle, which may partly explain this difference in cost estimates. However, the main reason for the lower cost per case treated in our study is probably because attendance at the mobile clinics was higher than that reported by Graves et al. (*1*). Hence mobile clinics may be a viable option if they are operated rationally, targeting areas of high transmission, and functioning only when malaria is most prevalent. Having mobile clinics as part of the control strategy may also provide some flexibility in countries such as Sri Lanka, where the disease pattern is highly unstable.

The capital and manpower inputs needed to upgrade a large number of peripheral hospitals with blood-filming units would be significant and could result in a very high cost per case treated in years of low malaria incidence. However, to be able to make use of the mobile clinics in a rational manner the health information system needs to be good enough to identify areas of high transmission quickly. An alternative strategy would be to establish village-level treatment facilities combined with the services of central hospital facilities.

The estimates that we have given in this article show that, from a government perspective, village-level facilities will probably never be as cost-effective as central facilities. However, inclusion of the cost to the households in the assessment indicates that village facilities provide considerable benefits to the community both by reducing direct expenditure and the time involved in seeking treatment (the opportunity cost of malaria to the households in the study area has been discussed in more detail elsewhere (*10*)). In addition, the village treatment centre may encourage people to seek treatment earlier, and thereby reduce the overall transmission of malaria. Assuming that accord can be reached between government health services and the relevant labour unions, a village treatment centre would provide an ideal opportunity to increase the community's involvement in diagnosing and treating malaria, with the people from the villages managing the centres under the supervision of experienced government microscopists. To determine the best mix of curative interventions, in addition to the health information system discussed above, an improved accounting system is also needed to facilitate decision-making.

The cost-effectiveness comparison between the residual spraying programme and the impregnation of bednets is based on the assumption that all the interventions are equally effective. This of course is debatable. It is assumed here that all individuals make use of bednets all year round, which may not be realistic. On the other hand, insecticide-impregnated bednets are very important in reducing the incidence of disease (*11*). Also, impregnated bednets have an impact on transmission both through the applied insecticide as well as by reducing the number of mosquito bites experienced by people using them, and they may therefore provide more effective protection than residual spraying. In addition, even though people may not use the bednets all year round they are more likely to use them during the periods with the most mosquitos. The newly introduced insecticides in the Sri Lankan residual spraying programme are still likely to be effective, but the comparison with malathion may no longer be valid owing to the development of resistance among some of the potential vectors (*12*). The insecticide spraying figures assume no wastage but studies should be carried out to quantify the true levels involved.

The effectiveness of the residual spraying activities also depends on community collaboration. This was not a problem in the study area but may be an issue elsewhere in Sri Lanka (*13*). However, the conclusion still holds that a bednet impregnation programme is a very cost-effective option for the government to pursue. New ways of implementing the programme should be explored, including training community representatives to be responsible for impregnating the nets, supervised by government staff. The cost of a vehicle for use in the impregnation programme is a significant expense but increased community involvement could reduce this, in addition to lowering the input of government staff. The cost to the household of purchasing bednets is high and probably prohibitive for a large segment of the population under the current socioeconomic conditions in Sri Lanka. Previous findings in the study area showed a significant positive correlation between household income and bednet use (*3*). A sudden change in focus from a residual spraying programme to bednet impregnation could therefore leave the poorest segment of the population unprotected. Ways of increasing bednet use therefore need to be explored. If a high coverage could be achieved, the cost-effectiveness of the impregnation operation would also be improved by increasing the number of bednets per day that could be treated by a team. Some of the proposals put forward by Evans (*14*) and Brinkmann & Brinkmann (*15*) on involving the private sector, nongovernmental organizations, and integrating the bednet impregnation activities into the routine health services are also of relevance in Sri Lanka.

In parts of Sri Lanka or elsewhere where natural streams are used as conveyance canals for irrigation water it is very important that the responsible government departments explore the possibilities for integrating water management objectives and malaria control activities. Managing water in local streams will save the health department significant sums of money and provide a low cost means of reducing the vector abundance for part of the year. It may be worth while also to examine the cost-effectiveness of other environmental management-based options.

The present study was carried out in a small area but we believe that its findings are valid for other parts of the dry zone of Sri Lanka. Furthermore, the small area approach made it possible to collect detailed information on inputs and their costs. The most important advantage was the collection of reliable malaria incidence data, which is often impossible for larger areas. The study included preventive and curative interventions that were actually taking place in the study area. Water management was included as an environmental control measure that has been worked out in detail for the area and is ready for implementation. Other preventive and curative interventions could have been included, such as the use of community health volunteers and the biological control of mosquito larvae; however, these were neither practised nor tested at the time of the study and estimates would have been speculative. ■

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Résumé

Coût de la lutte antipaludique à Sri Lanka

Cette étude donne une estimation du coût de diverses mesures de lutte antipaludique mises en œuvre dans une zone située dans le centre-nord du Sri Lanka, où la maladie est endémique. Nous avons supposé que chaque mesure avait la même efficacité. Nous avons estimé à 48 roupies sri lankaises (ReSL) — soit US $0,87 — par personne et par an le coût de l'imprégnation des moustiquaires achetées à titre privé, soit moins de la moitié du coût du traitement d'un logement par un insecticide à effet rémanent. La destruction des larves de vecteurs par épandage de larvicides, mais surtout par inondation des gîtes larvaires en procédant à des lâchers d'eau saisonniers depuis les retenues situées en amont, s'est révélée plus économique que les autres mesures de prévention (respectivement ReSL 27 ou US $0,49 et ReSL 13 ou US $0,24 par personne protégée). Si l'on tient compte des dépenses de fonctionnement et de l'investissement que représente le traitement des malades, on constate que pour les pouvoirs publics, c'est un hôpital central desservant une zone relativement étendue qui est le plus économique (ReSL 71 ou US $1,29 par malade traité). Les dispensaires mobiles (ReSL 153 ou US $2,78 par malade traité) et les centres antipaludiques de village (ReSL 112 ou US $2,04 par malade traité) représentent les options les plus coûteuses pour les pouvoirs publics, mais pour les ménages, leurs services sont beaucoup moins chers que ceux des hôpitaux traditionnels. Ces résultats peuvent aider les pouvoirs publics à choisir la combinaison la plus appropriée de mesures préventives et curatives pour combattre le paludisme. Il reste que l'option la plus économique pour le secteur public n'est pas forcément la moins coûteuse pour les ménages, et d'autres travaux seront nécessaires pour évaluer l'efficacité des diverses mesures de prévention.

Resumen

Costo de la lucha contra el paludismo en Sri Lanka

En el presente estudio se calculan los costos de diversas medidas de control del paludismo en una zona endémica del centro norte de Sri Lanka. Partimos de la hipótesis de que todas las medidas eran igualmente eficaces. Sobre esa base, el costo de impregnar con insecticida mosquiteros adquiridos por particulares se calculó en Rs 48 (US$ 0,87) por persona protegida por año, menos de la mitad del costo de pulverizar las casas con insecticidas residuales. Se estimó que la aplicación de larvicidas en los criaderos de vectores, y especialmente la eliminación de dichos criaderos mediante la liberación estacional de agua a partir de embalses situados aguas arriba, resultaba más barata que otras medidas preventivas (Rs 27 (US$ 0,49) y Rs 13 (US$ 0,24) por persona protegida, respectivamente). Considerando los gastos tanto de funcionamiento como de capital, la intervención más eficaz en relación con los costos para el Estado resultó ser la proporcionada por un hospital central con un área de captación relativamente grande (Rs 71 (US$ 1,29) por caso de paludismo tratado). Los consultorios móviles (Rs 153 (US$ 2,78) por caso de paludismo tratado) y los centros de tratamiento de aldea (Rs 112 (US$ 2,04) por caso de paludismo tratado) fueron opciones más costosas para el Estado, pero considerablemente más baratas para las familias que los servicios hospitalarios tradicionales. Esta información puede orientar a los planificadores sanitarios y los encargados de adoptar las decisiones a nivel estatal a la hora de elegir la combinación más apropiada de medidas curativas y preventivas para combatir el paludismo. Sin embargo, la opción más barata para el Estado puede no serlo para los residentes, y se necesitan aún más estudios para calcular la eficacia de las diversas medidas preventivas.

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