Ann. Soc. belge Méd. trop.
1995, **75**, 81-103

SOME OPERATIONAL ASPECTS OF THE USE OF PERSONAL PROTECTION METHODS AGAINST MALARIA AT INDIVIDUAL AND COMMUNITY LEVEL

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Résumé – La lutte antivectorielle, sélective et durable, est l'une des quatre composantes de la Stratégie mondiale de Lutte contre le Paludisme (OMS, 1992) et représente l'une des premières méthodes de prévention de la maladie parasitaire. De nombreuses méthodes de lutte contre les anophèles sont toujours disponibles et valables; leur choix est fonction des contextes éco-épidémiologiques et des contraintes socio-économiques. Les classiques aspersions pariétales intradomiciliaires conservent tout leur potentiel, notamment en zone, ou période, d'épidémie, mais ont leur limitation. En zone d'endémie palustre stable, il est justifié de développer des méthodes de protection individuelle et familiale comme les moustiquaires imprégnées, qui ont montré une grande efficacité dans la réduction du paludisme (transmission, incidence, fortes parasitémies, morbidité voire mortalité) lorsqu'elles étaient employées à grande échelle. Les problèmes opérationnels relatifs à la promotion et la mise en oeuvre des moustiquaires imprégnées peuvent, de façon didactique, être regroupés selon 4 thèmes majeurs: problèmes techniques, socio-culturels, économiques et pratiques. Dans le présent article, nous examinons quelques aspects de ces problèmes à la lumière des travaux récemment réalisés en Afrique, au Sud du Sahara, pour en tirer les enseignements facilitant l'applicabilité des moustiquaires imprégnées et leur adoption par les communautés.

Introduction

In the Global Control Strategy for Malaria (83) vector control is considered as one of the preventive measures for malaria control which must be selective and sustainable. Selective vector control is the application of targeted, site-specific control methods that are cost-effective (84) and no more the strict application of one method which has to be applied everywhere (66).

Many methods are still available for vector control against malaria transmission and disease prevention (91), from residual indoor spraying to larval control through personal protection-measures, taking into account the level of vector resistance to insecticides (82) and their applicability in local prevailing conditions. As it was well underlined recently (84) in any vector control activities (VCA), integrated in the national malaria control programme (MCP), some steps have to be considered before their implementation:

1. to define the objectives of the VCA itself in MCP;

2. to specify relevant indicators for a permanent evaluation, and even reorientation of the programme;

3. to specify the data required for these indicators and how to obtain them.

Considering that the principal objective of vector control is the reduction of malaria morbidity and mortality by reducing the levels of transmission, the indicators will be both entomological and epidemiological.

But the process of an adequate implementation of VCA will depend on a sound knowledge on *how* the various actors and components of the malaria disease actually interfere in the situation considered. Indeed, to reach their full efficacy, vector control measures must be *adapted* to both ecoepidemiological conditions and socioeconomic constraints (91).

The recent outbreaks of malaria in the high plateaux of Madagascar (79) has well demonstrated that house-spraying (with DDT in this case) could still be a very useful method and could be recommended in some epidemic situations. House-spraying (with malathion) was also very efficient in the campaign recently carried out against malaria vectors in the framework of a rural development project in Burundi (5). But it is often difficult to implement it on a long term basis as it is necessary in endemic countries with stable malaria transmitted all year round (Group I of Wilson) (9) or with a regular long lasting season of transmission (Group II of Wilson) (9).

Larval control should be efficient in special circumstances (3) or environmental modifications could be made for source reduction (80) in some conditions.

Having recognized the efficacy of these methods in some places or situations, one of their main issues are their operational constraints (64), such as the lack of long term applicability and implementation with community participation.

Therefore a new interest was given to personal protection measures, such as insecticide impregnated bednets and other materials against malaria vectors (24). Individually used insecticide impregnated mosquito nets (IMN) is a good tool for *protection* against mosquitos: used at a large scale they are a good method of *prevention* of malaria.

It is important to distinguish between the *promotion* of impregnated materials through public education and their *application* as an intervention for malaria control aiming at a certain coverage of a given population and funded, fully or partially, by public funds. In the latter case it is important that their *efficacy* under local conditions has been documented and that *sustainability* can be ensured (84).

Protection and prevention, promotion and application, efficacy and sustainability, are some of the key words linked to the operational aspects of a vector control programme integrated in the National Malaria Control Programme, based upon personal protection measures for disease prevention and which must consider several operational issues.

Operational objectives and indicators

Operational objectives and indicators for personal protection measures have recently been specified in the meeting of the Regional Working Group on Malaria Control in the African Region (Brazzaville, 15-18 March 1993).

Outcome objective

By year_____, increase to _____% the proportion of households targeted for use of nets using at least one impregnated bednet.

Several indicators could be elaborated according to local constraints and condition, but from a general point of view they could be related to house-hold, or community, use of IMN.

Among others we could highlight the following:

House-hold oriented indicators:

- denominator : number of households targeted for use of impregnated bednets;
- numerator :
  - per household, the number of beds equipped with one bednet (or at least only bed of pregnant women and young children);
  - during the transmission period the number of bednets properly used;
  - during the transmission period the number of bednets which were impregnated (or reimpregnated) during the past 6 months;
  - number of households for which impregnated bednets are actually affordable in terms of costs;

Community-oriented indicators:

- denominator: number of targeted villages (or communities);
- numerator:
  - per village, the number of well trained personnel,
  - villages with a minimum stock of insecticides and nets and material needed for impregnating bednets,
  - villages with organized information, education meetings eventually, common dipping session, etc.

A development process has to be elaborated on how to choose the necessary data, their sources, how to access them, who to analyze, interpret and use them, as well as how to get feedback.

Personal protection methods

Several personal protection methods are available against vectors of diseases (25): bednets, which are well known for a long time (44), repellents which can be spread on the skin (58, 22, 23), or incorporated in soap (45, 86) or sprayed on clothes (37), mosquito coils (8), electric mats and burning of local plants, etc.

A great number of repellents are available but they have all a relatively short efficacy (no more than a few hours) (22). They must be used with some care because they might have serious side effects (87); they protect the user only and are costly. They could be used by special groups of people, (travellers, army etc.) who are not staying for a long time in the region. These products cannot be considered as a good tool in public health in endemic countries.

Mosquito coils are largely used with positive (8, 18) or negative data (21) and they might have different influences on mosquitoes behaviour.

Even if the price of a single coil is low, the final cost is high because they last only a few hours (6-8 hours), and must be replaced every evening (or night). One of their advantages is that they can be used outside, mainly during

the evening and the beginning of the night when people are still outside for their social life. But as they are, they could hardly be considered as an efficient tool for malaria control.

Usual mosquito nets have some obvious advantages but also disadvantages. Well used they constitute an efficient mechanical barrier between men and mosquitos (and other biting insects).

In The Gambia, according to the pattern of activity of *Anopheles gambiae s.l.* the percentage of bites that might be received by protected people whilst they are not under their bed nets is approximately 10.5% and therefore, if well used, a bednet can give a 90% protection against the bites of this species (75).

Bednets have, however, some drawbacks:

- bednets are usually torn and not repaired and mosquitos can find any small hole of the net and enter it;
- mosquitos can easily enter a not carefully tucked bednet;
- mosquitos can easily bite any part of the body which is in contact with the net;
- hungry mosquitos enter a house even if bednets are hung, and they fly nervously around this inaccessible bait making noise (mainly *Culex*, the urban mosquito) and disturbing the sleepers;
- people complain about the warmth under roughly made bednets or other feelings (claustrophobia...);
- bednets do not kill the mosquitos and, at most, they have some protecting effect as long as the sleeper is under the net but there is no general impact on the mosquitos population.

Hence, they do not have great efficacy in preventing malaria in endemic countries (12, 75).

Technical operational issues of impregnated mosquito nets (IMN)

The recently developed method of pyrethroid-impregnated mosquito nets (IMN) and other materials (81) really appeared as an Appropriate Technology in Vector Control (24).

Trials carried out in many countries with ecological and epidemiological different situations gave strong evidence that insecticide-impregnated bednets (and other materials) are efficient for malaria control in reducing transmission, incidence of parasite, prevalence of high parasitaemia, malaria morbidity and even mortality (4, 7, 15, 36, 70).

The technique of insecticide-impregnated materials can therefore be considered as a new tool available in public health for malaria control. But, from a technical operational point of view, four major issues must be considered: entomological aspects; insecticides used; techniques of impregnation and net materials.

Entomological operational issues

Two elements must be considered at this level: the influence of impregnated bednets on targeted species (= malaria vectors) and their "collateral effect" on other biting or disturbing arthropods.

Targeted species

Insecticide-impregnated mosquito nets are really useful against endophagic/anthropophilic night biting species such as *Anopheles gambiae* (40, 70) but should be less efficient against exophagic and zoophilic species such as *An. sinensis* in China or species biting mainly outside at the beginning of the night such as *An. albimanus* in Haiti or Peru, or *An. culicifacies* in Sri Lanka.

In the three year trial in the Buji district (China) the outdoor catches of *An. anthropophagus* (endophagic/anthropophilic species) decreased by 85% but *An. sinensis* (zoophilic) by 36% after the implementation of treated nets (52).

In the rice field area of Kou valley, (Burkina Faso), most of the infected bites of *An. gambiae* occurred during the second part of the night (70). This behaviour explained why the large scale use of treated nets "resulted in a 94% reduction" of the malaria inoculation rate in this village (70). The transmission measured by the inoculation rate is always estimated in non protected persons.

In a savanna village of the same area, malaria transmission was reduced by 82% after the introduction of deltamethrin impregnated bednets (14).

In Zaire the *An.gambiae* inoculation rate decreased by 98% after introduction of deltamethrin treated bednets (40).

In villages of the forested area of Cameroon introduction of deltamethrin treated bednets induced a decrease of 78% of malaria transmission by *An. nili* and *An. gambiae* and their vectorial capacities were reduced by 99% (43).

In The Gambia there was a 90% reduction in the blood feeding success of vectors in villages with treated nets (76). It was also estimated that over 90% reduction in biting on man by *Anopheles gambiae* Giles s.l. was obtained in the four hamlets where bednets of inhabitants were treated with permethrin (46). Actually the net impregnated with 500 mg permethrin per square meter gave the best individual protection reducing blood feeding (of *An. gambiae*) by 91% compared with untreated nets (48).

Such similarity of data is worthwhile and clearly demonstrate the efficiency of IMN in reducing *An. gambiae* malaria transmission.

On the other hand a small scale trial recently carried out in Congo (90) has shown that the presence of deltamethrin treated bednets inside the house induced a sharp decrease of density but not a shift in the biting cycle of *An. gambiae.* However, a shift in the biting behaviour of *An. farauti* was observed (19), this species biting earlier than before the introduction of permethrin impregnated nets (it is known that this pyrethroid has a strong deterrent effect).

Therefore it has to be kept in mind that operational applicability of impregnated bednets is well linked to the actual, and potential, behaviour of species involved in local transmission of malaria.

Another advantages of insecticide treated bednets lies in the fact that even when torn, at least to a certain extent, they confer some protection to the sleeper (16).

As insecticides induce a drop in the frequency of man/vector contact, in density and in longevity of anopheline anthropophilic population, the final result of a large scale use of insecticide treated bednets is an important reduction of transmission in concerned localities. Consequently the malaria morbidity decreased to some extent even in holoendemic area (7, 15, 36, 77) and this fact could contribute in gaining actual community participation in vector control activities.

Collateral Effects

Moreover this impact on malaria vector themselves, IMN could have a remarkable influence on other biting and disturbing arthropods ("collateral effect").

In a rural part of The Gambia, the influence of insecticide-treated bednets on nuisance arthropods usually found inside houses was spectacular (47). At the beginning of the study 37.5% of children beds were infested with bedbugs *(Cimex hemipterus),* 3.9% with chicken ticks *(Argas persicus)* and 28.8% of the children < 10 years had headlice *(Pediculus capitis).* The dipping of the bednets in permethrin induced a reduction of 100% of bedbugs, 100% of ticks and 78.6% of headlice, and 86.4% of other flying insects. According to the authors "both bedbugs and chicken ticks were considered to be major nuisances and their eradication was appreciated greatly by the inhabitants of the hamlets", a key point for the sustainability of the method.

Indeed, in Papua New Guinea, "bednets impregnated with permethrin effectively controlled the bedbug population for at least 10 weeks... The control of lice and bedbugs by impregnated bednets is one of their most positive attributes. This is the main reason why people wanted their nets re-treated..." (20).

In the Solomon Islands, "the fact that the treated nets kill head lice is a positive factor... the end point of residual effectiveness of the permethrin treatment can be indirectly determined by recording the date villagers detect a return of head lice" (74).

The collateral effects of treated bednets are most welcomed by the population (61), stimulating their actual participation in using treated nets and even asking for their re-treatment, a crucial factor for the durability of vector control activities.

Insecticide-impregnated bednets should also be useful against other vector borne diseases. Recent trials in zoonotic cutaneous leishmaniasis foci in Sudan showed the great efficacy of IMN with a sharp decrease of the biting rate of *Phlebotomus papatasi* (Desjeux, pers. comm.).

It was also attributed a very strong protective effect of the bednets impregnated with pyrethroid on Japanese encephalitis in a trial carried out in Gusi county, Henan Province (China) and it was considered that "impregnated bednets might be used in an emergency situation of Japanese encephalitis outbreaks" (55).

Operational insecticides

The trial of OP (organophosphorous) insecticides (fenitrothion, chlopyrifos-methyl, chlorphoxim and pirimiphos-methyl) in 1975 at the WHO Collaborative Centre of Soumousso (Burkina Faso) was unsatisfactory (11). But in the same place the trial was happily successful when bednets were impregnated with the well known and used permethrin pyrethroid (28).

Various pyrethroids are now currently used for impregnation of bednets and other materials (25), mainly permethrin (200-500 mg a.i./m^2 of net), deltamethrin (10-25 mg a.i./m^2) and recently lambdacyhalothrin (10-25 mg a.i./m^2) and alphamethrin (20 mg a.i./m^2). They are used as a general rule as emulsifiable concentrates (EC) or flowable concentrate (SC) while wettable powder (WP) was also used with deltamethrin and alphamethrin (91, 92).

These pyrethroids are fast acting, persistent and of low mammalian toxicity at the low dosages required for bednets and curtains (6, 78).

Cypermethrin (t.d. 100 mg a.i./m^2), deltamethrin (t.d. 25 mg a.i./m^2), lambdacyhalothrin (t.d. 25 mg a.i./m^2); permethrin (t.d. 500 mg a.i./m^2), and pirimiphos methyl (t.d.1000 mg a.i./m^2) were recently tried against *An. gambiae* s.l. and *Mansonia africana* in experimental huts (59). It was concluded "that permethrin tends mainly to deter mosquitoes from house-entry, enhancing personal protection, whereas the other insecticides kill a higher proportion of the endophilic mosquitoes, which would give better community protection against malaria transmission".

Permethrin usually revealed a strong deterrent effect which limits the entering of *An. gambiae* in houses furnished with permethrin-treated nets (28, 49, 50, 59, 68).

Deltamethrin or lambdacyhalothrin are often preferred for bednet treatment because they have a faster killing effect and therefore could have a better impact on prevention of malaria transmission.

On the other hand "lambda-cyhalothrin was considerably more toxic than permethrin (against *An.gambiae);* i.e. 2.5 mg/m^{-2} lambda-cyhalothrin was at least as insecticidal as 1,000 mg m^{-2} permethrin" (60).

These pyrethroids induce different behavioral response (60) from irritant effect to mortality (immediate or delayed) of mosquitos according to species involved, insecticides and concentrations used and support material. The insecticide must be "fast acting" because "on a treated net the longest time spent by a mosquito was 3 min, whereas on an untreated net a maximum of 21 min was recorded as time spent resting and searching for a suitable place of entry" (38). Therefore the "knock-down" of mosquitos coming into contact with treated surfaces is interesting from an operational point of view because specimens, even temporarily knocked down, will fall on the floor where they will be consumed by scavenging animals and no more acting in malaria transmission.

The bio-degradability and good adherence of permethrin on bednets with its low toxicity for man must be underlined (68) and it is also the insecticide of choice for impregnation of clothes.

The keys technical elements of insecticides to be used are actually their safety for men and the environment and their *efficacy* on targeted species (and other pests nuisances). The problem of *resistance* has to be managed because large scale use of insecticide treated nets, or other large scale use of insecticides for agricultural or domestic use, could lead to the appearance/selection/spread of resistance. The management of possible resistance is crucial from an operational point of view.

In Bouaké (Côte d'Ivoire) according to WHO criteria "there is no doubt about the resistance of *An.gambiae s.s.* to permethrin" while "the resistance to deltamethrin and lambdacyhalothrin is a debatable matter" (34).

In Kenya it was noticed a "reduced susceptibility of *Anopheles gambiae* to permethrin associated with the use of permethrin-impregnated bednets and curtains" (89).

Recent trials carried out in Cameroon showed that *Culex quinquefasciatus* seems less susceptible to insecticide impregnated bednets than *An. gambiae* and this point has to be considered when implementing a vector control programme in urban areas expecting the participation of population which could reject the method leaving the nuisance still acting.

Still in line with the operational point of view, an issue which has to be taken into consideration is the wash-resistant power of the formulation used. Actual-

ly the washing of bednets causes a great loss of insecticide and nets have to be retreated, a major drawback for sustainability of the method.

It was recently showed that "washing three times in the traditional manner, with local cow-fat soap, reduced the initial dosages by about 85% of cypermethrin and lambda-cyhalothrin and 99.8% of pirimiphos-methyl, and left no detectable residues of deltamethrin or permethrin" (59).

Different formulations of permethrin (EC 25%; EC 10%) and a wash-resistant one (EC 25% plus 5% polystyrene 100.000 m.w., BDH) at a t.d. of 500 mg/m^2 were recently tested against *An. gambiae s.l.* (68). It thus appeared that:

- "the Wellcome and wash-resistant formulations (permethrin) still lost about 85% of their deposit on washing of nylon nets. The loss was less from the cotton nets";
- "the cotton nets caused most deterrency, both before and after washing, probably because they absorbed more of the formulation than others nets".

A wash-resistant formulation of permethrin gave major benefit as nets impregnated with it "retained their insecticidal properties better than nets impregnated with lambda-cyhalothrin or with the standard permethrin formulation", actually "after three washes the standard permethrin treatment caused the lowest mortality (of *An.gambiae* in bioassay) and the wash-resistant permethrin treatment gave significantly higher mortality" (61). From an operational point of view this is very interesting according to "the frequency with which (people) wash their bednets" (61) and this property of new wash-resistant formulation will be helpful to implement IMN even in people who frequently wash their nets (71).

In Surinam, it was noticed that "cotton cloth impregnated with permethrin, at a rate of 0,5 g/m^2, killed all *An. darlingi* females exposed for 2 minutes but after the material had been washed twice, the bioassay mortality fell to only 21.4%" (71).

The long lasting effect of insecticide is also a key element from an operational point of view. Several trials were carried out in laboratories and in the field to evaluate this effect.

In bioassay (30') with deltamethrin (25 mg a.i./m^2 on cotton) it was observed that 93-100% mortality (of *An. dirus)* was obtained with the deltamethrin-treated nets, 15-544 days after impregnation (51).

In spite of some recent advertising we do consider that, from an operational point of view, without washing or other special events, well treated nets can protect sleepers (and the community) against the bites of *An. gambiae s.l.* for approximately 6 to 8 months and it was also considered that "a deltamethrin-impregnated bednet (10 mg/m^2) is effective for 6-7 months" against Chinese vectors (85).

Operational techniques of Impregnation

For psychological reasons it is important to undertake the treatment of nets in the village, with people watching, so that they can see that the insecticide (which smells) is actually put in/on their nets. At the same time they can learn "how to do the impregnation" for further use by themselves.

Impregnation of nets can be carried out one by one (individual) or by lot (= collective treatment) according to the situation.

Impregnation can be done by dipping the net in a container where the right amount of insecticide solution has been prepared, or by spraying the material with a standard hand compressor.

Dipping is very easy to do (42, 73) and everyone can quickly learn how to proceed to obtain a good impregnation after little training, directly in the field, without any particular knowledge on insecticides (91).

The use of deltamethrin, in its presentation EC 2.5% is convenient as it contains 25 g a.i./l. e.g. 25 mg/ml, and the target dosage is 25 mg a.i./m^2 of net. Therefore 1 ml of product is needed for each m^2 of net, without any further calculation.

Individual impregnation by dipping can be done in any container with some precaution, such as gloves, or it can be done in a plastic bag. It is now made easier with the "monodose", e.g. a small container (bottle or plastic) which contains the right amount of insecticide to impregnate one bednet of the usual size (12-15 m^2).

Collective impregnation by dipping can be done in a large bowl or in a barrel divided in two parts. One side is used for dipping the net which is then crushed above the second half to collect the excess of insecticide solution.

Before starting the operation the volume of water absorbed by the net must be known, cotton absorbed about twice as much water as nylon, otherwise there are no special technical problems in impregnating bednet with this method (91).

Some training is nevertheless needed before leaving any community trying to do a collective dipping of their nets. From an operational point of view great care must be taken for "dippers" (irritant effect of insecticide) and environment when washing the containers and "empty" bottles of insecticide, etc.

The spraying of nets could seem more difficult to implement through community participation. In fact it is very easy to do when working with farmers who know and use insecticide and sprayers. They can learn how to use them and how to spray their nets very easily. One of the great advantages of spraying is its speed, a bednet can be sprayed in 15" and when dealing with a great lot of nets it is much easier and faster to spray than to dip them. Some care must be taken, one of them being the wind because spraying must be done outside with all nets hanging on a usual string for clothes. Spraying is used at a very large scale in Sichuan province of China with deltamethrin at a target dosage of 9.6 to 12 mg a.i./m^2 and gave impressive results on malaria incidence cases (26).

Operational nets and other support material

A large variety of nets are currently available and used, home made or industrialized, heavy/light material, strong/fragile material, with different mesh (number of holes/square inch), different weight (denier 40, 75 or 100), breaking tenacity, colour, size, shape, etc.

It seems that denier 75 and mesh 156 with knitted multifilament thread is the best compromise in term of solidity/weight.

A single bednet has about 8 m^2, while the "Spider" has some 23 m^2. They can be conical, rectangular, half-cubic, with or without slit-door, with or without sheeting border, according to any choice, financial possibilities, available space in rooms, etc.

Some people prefer the heavy, opaque textile for their privacy, others like light material due to warmth inside nets, some want small holes to avoid mosquitos entering the net, others prefer larger holes to have more "fresh-air", some do not like a white colour (= shroud) or like bednets as outward signs of wealth, etc.

Bednets can be made of cotton, nylon, polyethylene, polyester or any other textile (for those made at home). One of the key points is that they must be fire-resistant to avoid problems which could occur in houses where people cook in the same room as they sleep. In the trials carried out in Tanzania, "three nets are known to have been damaged by fire. However, the nets burned slowly and there was plenty of time for the occupant to escape" and the flammability of nets is a matter of concern (65).

They can be bought ready-made, or as nets (rolls of 100 or 200 yards, width 78 inches, are available) which are locally tailored according to choice and possibilities of customers.

They can also be bought already impregnated (with permethrin or deltamethrin) or with insecticide incorporated in the net. In this case they are more expensive than the untreated ones.

The efficacy and long lasting effect of insecticide varies according to support and chemical used.

Cotton netting significantly reduced the toxicity and irritancy of the permethrin treatments. *Culex quinquefasciatus* was less irritated by permethrin but more by lambdacyhalothrin (60).

In China the study of the toxicity of pyrethroids adsorbed on different fabric (85) showed that at a dosage of 10 mg a.i./m^2 the KT95 (time to kill 95% of mosquitos) values (minutes) were:

	PERMETHRIN	DELTAMETHRIN
An. sinensis		
	nylon 15.2	17.1
	cotton 47.9	10.8
An. anthropophagus		
	nylon 21.2	15.7
	cotton 27.2	12.2
Culex quinquefasciatus		
	nylon 38.6	17.5
	cotton 130.5	20.1

"On cotton and nylon bednets, the half-life of deltamethrin was 65.6 days and 55.4 days, whereas the half-life of permethrin on cotton and nylon bednets was 35.0 and 27.4 days" (85).

Permethrin appeared considerably more effective on polyester than on cotton and there was little difference between the fabrics when deltamethrin is applied (24).

Sociocultural operational aspects

One of the key points in the implementation of large-scale use of insecticide impregnated bednets is the active participation of community in using them, taking care of them and reimpregnating them correctly when needed.

According to local situations, special trends in promotion of bednets will be elaborated.

The study of acceptability of nets, types of nets preferred, acceptance of insecticide treatment, affordability, washing of nets, the sleeping time, etc., has made it easier to adapt the net programme planned so as to accept local habits and preferences (56) rather than trying to change them in favour of a technically optimum form of mosquito protection (33).

The usual behaviour of populations against mosquitos, and other disturbing insects, needs therefore to be well known (2). Two situations can be observed: either people are doing "nothing", or they are doing "something".

In the first case the question is: why? – because no particular nuisance is felt? lack of money? lack of willingness? Would they do something if they got special support, and if yes, which kind of support? funds? information? training? materials? In the case of materials, which materials, bednets? insecticides, etc.? Promotion of vector control will be elaborated according to these information.

If people are doing something, some of the main issues are:

- Why are people doing something against mosquitos and how and when?
- How much does this "mosquito control" cost?
- Why people are using bednets (or do not and who used them)?
- What is (or should be) the compliance/acceptability of bednets and insecticide treated bednets?

From an operational point of view it is indeed of paramount importance to know the current use of bednets as it is easier to implement the impregnation of these nets than to convince people to sleep under mosquito nets when they did not.

Cluster sampling surveys carried out in different towns of Central Africa (29) showed that bednets are largely used in humid forested areas: Brazzaville (60%), Lambaréné (68%), Bangui (70%) as in the humid maritime regions: Port-Gentil (61%), Douala (50%) or in the savannah area on the skirts of Logone: Bangor (67%). On the contrary, the use is less developed in Bassangoa, CAR (16%), and both Bilalang (10%) and Yaoundé (5%) (Cameroon).

In West African communities it appeared that "bednets were used to a varying extent, from 44% Ghana to 86% Gambia, in each community to protect against mosquito bites" (2).

Knowledge, Attitudes, Practices (KAP) surveys recently carried out in Cameroon (30, 31, 32) gave the following information:

- more than 70% of people are doing something against mosquitos.
- Various methods are used according to place:
  - Yaoundé: sprays (#50%), then coils (20%);
  - Douala: bednets (#50%) then sprays (45%) and coils (42%);
  - Ekité: mainly coils (54%), then sprays (20%) and bednets (14%);
  - Bilalang: aerosols sprays (30%), then bednets (13%).

In South Cameroon, 95% of the urban population surveyed complained about nuisances due to mosquito bites (50-60%) and noise (10-20%) and

against diseases transmitted (20-30%). We noticed that bednets were mainly used for babies in the town of Yaoundé and for adults in rural surrounding parts (unpub. obs.).

KAP surveys carried out in Kinshasa (88) among 420 families showed that:

- 92.4% of interviewed people considered to be disturbed by mosquitos:
  - 71.1% from bites
  - 52% from disease
  - 45.8% from noise
  - 2.6% from tiredness
- > 80% are doing something: 85.6% bought coils; 55.5% bought sprays; 46% bednets; 5.2% asked for official national services, are also used local products for house spraying (21%); gasoil (7%); plants (1%).
- There is a strong statistically significative association between the education level of interviewed people and the use of bednets; on the other hand useless methods are related to a low level of education.

In The Gambia cultural preferences were noticed in the use of beds (56). 99% of rural Mandinka were sleeping under bednets made by local tailors, but use of bednets was less popular in Wolof (64%) and Fula (58%) villages, even if the economical situation of their villages was similar. In recent studies it was found (1) that:

- 99% of users of bednets used them in the wet season for protection against mosquito bites.
  Apart from protection against mosquito bites the other reason for using bednets are:
  - privacy 66%
  - protection droppings 13%
  - warmth 13%
  - other reasons 9%
- 62% of users claimed that bednets prevented them from having malaria.
- Older people were more likely to use bednets than younger subjects.
- The majority of non users (58%) claimed that they could not afford to buy nets, "this assertion was unlikely to have been true since most farmers in the harvest season have money to spend on jewellery, clothes and adornments" (1). These observations corroborated those made in Edea (Cameroon) where workers of a factory claimed about the price of mosquito nets which, in fact, were given free of charge! (unpub. obs.). It is also worth noticing some lack of re-treatment of nets being considered as "too costly" while it costs less than one local beer or soft drink and gives about six months of protection against mosquitos and other disturbing pest. It seems that it is mainly a problem of "priority", health-related equipment for prevention appeared to receive low priority compared to other goods and services by some groups of people;
- Girls used bednets significantly more frequently than boys, and this was noticed for all age groups.

- Adolescent boys often slept outside without nets.
- Fulas (mainly herdsmen) did use nets when they lived in villages with very high mosquito density.

Actually in Chad, Doundé (pers. comm.) noticed that people living on the edges of Lake Chad, where the huge population of mosquitos is a very painful nuisance, had bednets, used them and even carried them during their nomadic displacements.

In the rice field area of Kou Valley (Burkina Faso) the proliferation of different mosquito genera *(Anopheles, Culex, Mansonia* and *Aedes) is so* great that the people try to protect themselves from mosquito bites by various means (coils, etc). Most people have developed the habit of sleeping under mosquito nets (13).

In the rain-forest of Surinam, where malaria is endemic, 95% of the Marsona and all Amerindiens use mosquito nets made out of cotton cloth or, less frequently, nylon or cotton gauze over their hammock or beds (71).

In the Chonburi Province (Thailand) the "sociological and cultural baseline data in using a bednet of migrant workers" were studied (33) and it appeared that "87% of long-term migrants (> 6 months before the interviews) and 72% of seasonal migrants (to cut sugar cane during the three months cutting season) gave the history of sleeping in a net every night; while 4% of long-term migrant and 15% of seasonal migrant workers had never slept in a net". On the other hand "seasonal migrants had a better perception of the benefits in the use of the nets than long-term migrants; 98.9% of seasonal migrants and 79.5% of long term migrants thought that sleeping in a net keeps one from getting malaria".

In China, the fact that "mosquito nets have been used world-wide for many years" was useful to develop insecticide-impregnated bednets at large-scale, treating directly the nets of people and gaining thus a good compliance (52).

In Papua-New Guinea mosquito nets are extensively used in areas where villagers have some access to cash income (35); bednet utilization is highest among children < 10 years of age (86.5%) and 10-14 years old (80.9%) but use of bednets decreased during the dry season (17).

Every study of human behaviour produces the same information, e.g. the main reason advocated by people for their daily fight against mosquitos is, always and everywhere, the nuisance: bite and noise. Then the fear of diseases transmitted by mosquitos, which range from malaria to AIDS (31, 32). It is worthwhile to underline the fact that in The Gambia where inhabitants of several villages had their nets treated with insecticide "the main reasons given for treating their nets were protection against mosquitoes (72%) and other insects, bed bugs and household flies (21%)" (1). Furthermore, 93% of the villagers said that they were prepared to purchase the insecticide permethrin for treating their nets through village, compound, or individual contributions, if the Government would supply it to the village (1), the same observation was recently made in Ebogo village (Cameroon) where insecticide impregnated bednets were successfully introduced (unpub. obs.).

Economical operational aspects

One of the major issues advocated by populations for their non use of bednets is often their cost. Actually there could be variables according to size,

material, options, etc. but normal mosquito nets can be bought for 2.35 US$ to 4.70 US$, according to size and strength and the target those of insecticide costs 1.35 US$ to 2.50 US$. An insecticide-treated bednet costs about 3.7 to 7.2 US$ at its factory. Travel costs, customs, trade benefits have to be added. Taking into account all these elements, the National Bednet Centre of Douala (Cameroon) sold bednets at about 12 US$. This price is affordable when considering the costs of other mosquito control methods used by the population of these areas.

As an average of 3.7 bednets are needed per family, it was estimated that the basic investment in bednets is about $3.7 \times 12 = 44.4$ US$, e.g. less than the cost of mosquito coils which disappear while bednets stay.

Actually the cost of mosquito control at house level was estimated at about 108 US$/family/year in Yaoundé and about 141 US$/family/year in Douala while the average monthly salary is about 398 US$ (31, 32).

There is a great variability of the cost of these in-house mosquito control methods (53):

METHOD	AVERAGE COST PER FAMILY/DAY (US $)	AVERAGE COST PER FAMILY/YEAR (US $)
Sprays	0.27	98.6
Coils	0.12	43.8
nets	0.13	47.5
sprays + coils	0.39	142.4

The cost of malaria disease varies according to the method. Self treatment of a malaria crisis is estimated at US$ 3.0; being treated at the dispensary it costs US$ 7.9 and US$ 30.5 in the main hospital. Considering the drug, used and kept in house, the incidence rate of malaria according to age groups and the usual behaviour, it was estimated that the total cost of "malaria" is about 120.7 US$/family/year in some urban situations in Cameroon (53).

Altogether malaria control at family level would cost annually (53):

ANTIVECTORIAL		TREATMENT OF DISEASE	FAMILIAL DRUG	TOTAL
mechanical	chemical			
8.6 US$	67.2 US$	96.6 US$	24.1 US$	196.5 US$

On the other hand:

- several studies carried out in subsaharian countries agree that there is a reduction of about 50% in malaria morbidity for people using regularly impregnated bednets.
- regularly monitored and repaired bednets last three to five years.

According to this information it appeared that to be protected against nuisance and malaria transmission, the use of insecticide-impregnated bednets is, without any doubt, a cost/effective method in this urban African situation.

In rural areas of The Gambia the cost of using locally-made nets was about 1.75 US $/person/year in December 1987 and its treatment with permethrin (0.5 g a.i./m^2) cost 0.30 US$, "therefore the cost per year for the use of an impregnated bednet was 2.05 US$" a price which seems affordable (57). Still in The Gambia a "cost-effectiveness analysis of bednet impregnation alone or combined with chemoprophylaxis in preventing mortality and morbidity from malaria" was recently done (67) and it thus appeared that "bed net impregnation alone and the combined strategy cost US$ 5.65 and US$ 7.49 per child-year protected respectively".

In Hainan Island (China) the costing of large scale vector control programme with DDT house spraying and deltamethrin-impregnated bednets were compared (51) and it appeared that in these places where "85% of people have nets costing 2.5 US $/person" the use of insecticidetreated mosquito nets is a cost/effective method (0.065 US $/person/year with deltamethrin on nets against 0.15 US$ with DDT as house-spraying) and it "will constitute a breakthrough in global malaria control" (51).

In Solomon Islands the cost of two malaria control operations, DDT house spraying and permethrin-impregnated bednets were compared and estimated as being annually of SI$ 8.53 and SI$ 3.85 respectively (41).

An analysis of "economic aspects of the use of impregnated mosquito nets as a strategy of malaria control" in many countries was recently carried out (10) and it was considered that "the cost of investing into impregnated bednets is outweighed by their benefits".

The economic issue of treated bednets is the initial investment when the head of the family has to buy six to ten bednets at the same time. Several possibilities could be elaborated to overcome this problem according to local structures:

- National structures could take off usual customs and intervene in such a way that bednets are available at a reasonable purchase price in a special place such as the National Bednet Centre of Douala.
- Workers of a large factory can receive a loan from the manager and they will reimburse progressively.
- Bednets could be given to agricultural workers, waiting for reimbursement with the harvest.
- Local financial structures could advance the money and reimbursement progressively made.
- NGO's or other structures can get bednets for the population and ask for participation in broadcasting to their family, neighbours, etc.
- Bednets could be given to schoolchildren to stimulate the purchase by their parents.
- The local shopkeeper can sell bednets on credit as it is usually done for goods.

In one way or another bednets should be sold and not just "given" to the population who will therefore take more care of them.

Operational aspects of Implementation

The availability of efficient methods is an indispensable requisite to any vector control programme but it has to be used in the more relevant manner for its actual integration in the National Malaria Control Programme and its acceptability by the population.

As underlined "the different social, cultural and epidemiological conditions make it necessary to design a strategy according to local circumstances in order to obtain the most acceptable and cost effective control method" (33).

The main factors determining the success or failure of implementation of treated bednets are the attitudes and practices of the population (30).

Implementation of malaria vector control with treated bednets needs a strong knowledge of current behaviour of the population (see above), then to *start* a project and to try to gain a total *acceptability* of the population and a progressive development of the new attitude in space and time (*sustainability*).

Implementation of a new method occurs in a health and social system which is different from country to country, and even inside the same country from region to region. The social system is a dynamic one with several components: cultural, technical, economical, historical, etc. which all interfere. Implementation will therefore be different according to management of health systems, human participation, financial support from public/private structures, local community funds, etc.

Therefore the solution of implementation problems could be found at unexpected levels *even outside the health system itself.*

What would appear as a technical problem (insecticide-treated bednets) must in fact take into account several factors which intervene before and after the technical component itself because it is (or should be) fully *integrated in the social system.*

The risk of failure for the implementation of any even application is important, if the social aspects (e.g. ethnological, anthropological, historical, etc.) of a targeted population are not enough taken into consideration in their different levels of intervention.

Community participation should be complementary to the action of health services to implement vector control programme at community level (62). All community participation relies on knowledge of the role of the vector and also of the disease which it transmits, in order to generate understanding within the population of the objectives of the proposed activities (63).

Health education, which should take into account the cultural background of the population, is the essential tool for dissemination of this knowledge.

Any proposed action should be compatible with local, cultural habits (56), and local community representatives should be consulted.

In some communities of Burkina Faso, for example, Bonnet (pers. comm.) has noticed that people link mosquitos to nuisance, fever to malaria (which could be cured by pills or local plants) and higher fever + convulsions, to the flight of a bird over their houses a couple of nights before. In such circumstances, to gain the actual community participation, the implementation of insecticide-treated bednets must be targeted on the reduction of nuisance (which will be obvious), on fever (which will be more or less obvious) but not on reduction of malaria mortality which has some surnatural origin in this society.

Among residents of the Pacific coast of Guatemala mosquitos are known to play an important role in malaria transmission and are thought to become infected by biting individuals with malaria. "75% of people interviewed believe that mosquitos can also acquire infections from contaminated water or by biting snakes and frogs. Furthermore, most residents believe that malaria can be acquired in other ways such as by bathing too frequently or by drinking unboiled water" (72).

This conception about malaria transmission could affect control measures not adapted to local beliefs. An educational campaign directed at correcting some of these misconceptions should result in more appropriate self-treatment of malaria and greater acceptance by residents of personal protection methods, vector control and drug treatment preparations (72).

In urban Pondicherry a survey showed that 80% of the people linked mosquitos to clinical symptoms of bancroftian filariasis, 9% blamed supranational forces and 4% blamed polluted water (Anonym, 1982).

Along the coast of East Africa, neither Arabs nor Bantus linked mosquitos and filariasis, although the nuisance of *Culex quinquefasciatus* led to requests for control measures (63).

Hence, two elements have to be considered in the implementing of IMN through community participation:

- health education which, in fact, will act at short term;
- continuity (sustainability) in activities being a long term issue.

A well defined health education programme with a good marketing/promotion of impregnated mosquito nets or other measures could lead to large acceptability if, and as long as, bednets are efficient against nuisance inside houses, not too boring in terms of maintenance and confer some social level to users. For example in some communities of West Africa bednets are used for decoration; moreover their usefulness against mosquito bites and "the majority of those who use nets have a family tradition of doing so" (2).

The feasibility of treated mosquito nets in a rural part of South Cameroon was studied by analyzing the behaviour and feeling of people who received impregnated nets for an operational research programme one year before the interview (54):

- 67% of given nets were still set up, one of the reasons advocated of the non-use was the inadequacy between the size of the nets and the size of the bed, an issue which can be easily solved;
- 32% of the nets were torn because they were not strong enough and easily damaged through normal use;
- 68% of users said they actually used the nets the previous night; 86% tucked the nets correctly;
- 76% got up during the night and 20% forgot then to tuck the net.

At the end of the study it was concluded that an average of 32% of those who had received the treated bednets free of charge did not use them, 47% used them correctly (54). The insecticide impregnation could balance the bad usage of bednets at community level. It is worth underlining the reasons pre-

sented by these interviewed people for their use of *treated* bednets and to compare with reasons advocated for the use of bednets:

- protects against mosquitos bites 85%
- kills all insects 12%
- protects against dirty things falling from the ceiling 2%
- reduces disease 1%

91% of people considered that treated bednets were useful and to a very large extent this influence is directed against the nuisance and not against the disease. It is interesting to noticed that this appreciation of treated bednets was similar whether they actually used the nets or not, demonstrating thus a well known human phenomena that to agree to a new method is not always followed by a change in current behaviour, even if the benefit seems obvious.

In Zaire, 800 impregnated mosquito nets (IMN) were given to people who never used nets, and 800 normal nets to people in another village which served as control. To implement the work a large education-information campaign with meetings and teaching aids was developed (40).

It thus appeared that people greatly appreciated the protection afforded by IMN against mosquitoes and bedbugs and 8 months after the distribution 96% of people actually slept under IMN (and 93% under normal nets).

In another trial carried out in South Cameroon, where workers of a factory received IMN free of charge in January 1988, a survey done in February 1992 gained the following data:

- 74% of interviewed people said they used IMN either daily (35%), or sometimes (65%). when it was not too hot; the main reason advocated for the non use was the inadequacy between net and bed.
- 83% of people knew that their bednets were treated with an insecticide, indeed large advertising was given to this operation in the village through the national TV and media. They knew that bednets were given by the factory but bednets were not re-dipped. 72% wanted such retreatment and 54% would even have accepted to pay for it. But no action was undertaken.
- 85% considered that IMN are very useful against mosquitos and 49% thought that IMN protect against malaria.
- 26% of the families were readily using their nets.

The main complaints against bednets were the feeling of warmth (which can be well understood because of the climatic conditions in this area), and the costs (which cannot be understood because bednets were given free of charge)!

In The Gambia 93% of people who had their nets treated with an insecticide two years before wanted to have them retreated (1).

Trials were recently carried out in Tanzania, in rural part where bednets are scarcely used due to their costs, IMN were given to several villages for their malaria control programme (65).

Several points must be underlined:

- Net distribution has been preceded by a one year regular visit to the villages, and two mass meetings were held in each village to explain objectives and methods. It was done so well that "only one person in all five villages refused to have a treated net".
- In the days following the distribution of nets villagers reported enthusiastically, and without prompting, on the death of mosquitos near nets and the disappearance of other pest insects, including bedbugs, fleas and even in some cases cockroaches.
- Public approval of impregnation of nets was shown by the enthusiasm with which nets were brought for re-impregnation at the appointed time (the first impregnation was done in the field station but the re-impregnation took place in the village).
- House to house surveys were carried out 6 or 12 months after distribution of IMN and "most showed signs of wear and tear, indicating that they were being used".
- "Compliance was very good with our request not to wash nets before reimpregnation was due" and people understood the presence of insecticide on the nets.

Hence it was considered that:

- treated nets are welcomed in Tanzania, even by those with no previous experience of using a mosquito net;
- the main benefit perceived by the villagers is protection against biting insects, in this study, as in several others, the disease prevention is not perceived as the first benefit from bednets;
- nets must be as durable as possible;
- "it is clear that impregnated nets offer a logistically straight forward method of controlling biting by malaria vectors, much simpler to set up and maintain than conventional house-spraying".

Rightly authors stated that "the main obstacle to the wide spread of treated nets in Tanzania is not acceptability but **affordability".**

This information related to the socio-cultural and economic aspects of operational issues in implementing treated mosquito nets on a large scale with and by people themselves.

It is worth underlining the fact that people from outside a place where impregnation of treatment is currently done come and asked for the treatment of their nets, showing that information spread quickly even without official advertising; we recently made these observations during the treatment of bednets in a part of Djibouti and N'djaména (Chad) (Carnevale, unpub. observ.). And when a method "works" people are ready to use it, as long as it works against disturbing insects, as noticed in several places such as Cameroon (54), The Gambia (57) or Papua New Guinea (20), where people wanted their nets re-treated because they killed lice and bedbugs and they "were prepared to carry them several miles in order to have this done" and they can spend some money for impregnating their bednets and improving their quality of life.

Conclusions

Considering that one of the key elements, from an operational aspect of vector control for malaria prevention, is actually the active participation of communities, several elements must be considered. In addition to its *"biological efficacy"* the method proposed must be *suitable* in terms of socio-cultural beliefs and behaviour, *affordable* in terms of cost-effectiveness perceived by the population, *available* in terms of material (net, insecticide etc), *attainable* in terms of local *possibilities, integrated* in a comprehensive action by health and other national and private structures. In other words the warrant of the success of a "vector control programme" is its *sustainability* which, from an operational point of view, is related to an easy-to-do and obviously efficient method against house-disturbing pests, creepy-crawler bugs linked to an easy-to-reach disease management system.

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