CONCLUSIONS
AND
RECOMMENDATIONS
In the laboratory evaluation significant difference was found in the performance of the three pyrethroids tested, that is lambdacyhalothrin emulsifiable concentrate, deltamethrin wettable powder and deltamethrin flow. Between the two fabrics tested, nylon nettings performed better than cotton because the chemical adsorbs well on the smooth surface of nylon fibres and is readily available compared to the rough crevices in cotton. It should also be considered that compared to cotton nets, nylon nets are cheap, light in weight, easy to maintain and last longer. Single washing after 3 months of use did not reduce insecticidal effect that much, however further washing was highly detrimental to all the pyrethroids and reduced the insecticidal efficacy. This should be borne in mind while introducing treated nets in places where nets are washed more frequently, such as, weekly in Suriname (Rozendaal et al., 1989) and fortnightly in The Gambia (Snow et al., 1987b).

Community use of nets treated with lambdacyhalothrin, deltamethrin WP and deltamethrin flow significantly reduced the indoor resting density of *An. culicifacies* and other anophelines in houses and cattle sheds, compared to untreated nets or no nets. This could be due to the mass killing effect of pyrethroids accompanied with irritancy and/or excito-repellency. Mass killing effect by treated nets was reported in Tanzania (Magesa et al., 1991) and China (Luo Dapeng et al., 1994a) also. The population of culicines was not affected markedly. Whether it is due to avoidance (behavioural resistance) or any physiological factor, needs to be investigated. Also, increase of dose to control culicines should be studied.

Partially lifted treated nets which simulated torn or improperly arranged nets, significantly prevented biting of *An. culicifacies* and other anophelines compared to untreated nets or no nets. About 86% of *An. culicifacies* bites were observed between 20:00 to 04:00 hours and Reuben et al. (1984) also reported 78% of bites during this period. This is the time-period when most of the persons were expected to
be under bednets. While the users of nets sleep comfortably, the treated nets not only act as a physical barrier but also kill the mosquitoes approaching them.

But those who go to bed late in the night or get up early in the morning or even those who work during the night, may have to adopt some other anti-mosquito device to prevent being bitten. Bednets should be properly tied, tucked in and well maintained. During day time they should be kept away from direct sunlight which degrades the pyrethroids. When people go to fields and sleep there to take care of the crops, they should be persuaded to take and use the nets there as was done during the present trial.

UV light traps were successfully used to collect mosquitoes during the trial. Traps set up in treated net villages caught significantly less number of An. culicifacies and other anophelines compared to villages with untreated nets or no nets. As attempts were made elsewhere (Lines et al., 1991) to correlate light trap collections and whole night human biting collections, it should be validated for Indian mosquitoes as well. It might be very useful to collect man-biting mosquitoes using light traps, since the conventional night biting collections are very tedious and could be risky.

In this study treated nets prevented feeding of mosquitoes as proportions of unfed females were more in villages with treated nets. Also, the longevity of vector mosquitoes, as shown by a reduction in parous rate of An. culicifacies was reduced. Treated nets significantly reduced the anthropophilic index of An. culicifacies and Cx. quinquefasciatus as compared to untreated nets and no nets, possibly due to diversion to cattle. All these factors contributed to reduction in malaria transmission to a great extent. Thus, although indoor resting densities of Cx. quinquefasciatus were not affected much, treated nets were still effective in preventing biting and diverting them to cattle, thus reducing the anthropophilic indices.
The target dose of 25 mg/m² gave 100% mortality of *An. culicifacies* up to 6-7 months. But even after 12 months of use the treated nets gave 53% (deltamethrin WP) to 78% (lambdacyhalothrin) mortality. Though Jana (1991) and Dev *et al.* (1994) suggested annual treatment, in this trial re-impregnation was done every six months during the second and third years to check malaria transmission in an effective way. Six-monthly re-impregnation was successful elsewhere also. The time of impregnation of nets has to be determined as per the seasonality of malaria vectors and length of malaria transmission period, besides of course the cultural practices of washing the nets.

It is already reported that, a higher dose of pyrethroid insecticides could have more of a repellent effect than a killing effect (Carnevale *et al.*, 1992). Hodjati and Curtis (1997) found that at a lower dose, permethrin gave 100% mortality so there would be no selection for resistance, but at a higher dose mortality was more in susceptible strain than F₁ hybrid, suggesting effective selection for resistance. So the correct dose and right time of impregnation are very essential for effective control. The re-impregnation should be done as per schedule with good coverage. One of the reasons for the failure of DDT spraying was not keeping up with the schedule and poor coverage.

Nets should be thoroughly washed before re-impregnation. Although soot deposits did not affect the efficacy of treated nets (Njunwa *et al.*, 1991), whether there is any difference in adsorption and efficacy between a newly impregnated, and an old, washed and re-impregnated net, needs to be tested. During this trial some people complained that the efficiency of re-impregnated nets was not so much as the first-time impregnated one. This might possibly be due to people’s perception because after the distribution of treated bednets the density of mosquitoes might go down, so also the nuisance of bedbugs, head lice and cockroaches which were earlier making the effect more obvious. Still it needs to be investigated.
Treated nets significantly reduced the incidence of malaria. Significant reduction was also seen in villages with untreated nets, but no change was observed in the village without nets. The parasite rate reduced significantly only in the groups of villages with treated nets compared to the villages with untreated nets or no nets. The risk of getting *P. falciparum* reinfection was significantly reduced by the treated nets compared to no nets, but the reduction brought out by the treated nets were non-significant as compared to untreated nets. Significant reductions were observed in spleen rate, child parasite rate and percentage of anaemia in the groups of villages with treated nets. All these only lead to the conclusion that mere physical barrier provided by untreated nets was just not enough but the chemical barrier provided by pyrethroid treatment was more important (Jana-Kara et al., 1995).

It may be argued that the use of bednets in summer was low but during that time due to the hot dry climate the vector density and malaria transmission were also low. Yet a considerable number of people sleeping outdoors used nets. Compared with indoor spraying of insecticide, use of nets outdoors was an added advantage. The bednet use was higher in cool season (November 1991 survey) when transmission of malaria was also high.

Untreated bednets did not give complete protection against mosquito bites. People reported that mosquitoes bit through untreated bednets and also live mosquitoes were noticed inside them. Mosquito nets though simple in the extreme, require a modicum of sophistication if it is to be used effectively (Gillett, 1985). On the other hand, even a considerably torn treated net could prevent man-vector contact in an effective manner (Carnevale et al., 1992).

Treated nets were appreciated by the community also because of various collateral benefits. Whether long term use of treated nets would lead to development of resistance in bedbugs, head lice, other insects or even mosquitoes for that matter, needs to be studied. Deltamethrin treated bednets did not produce any resistance in vector mosquitoes even after seven years of usage in China (Kang et al., 1995). But
caution is required when going for mass impregnation for a longer period, because of the reduced susceptibility observed in Kenya (Vulule et al., 1994). Even in this trial Cx. quinquefasciatus showed tolerance and its indoor density remained largely unaffected though pyrethroids did repel/deter them from baits.

Compared to DDT spraying, impregnation of people's own net is cheaper (Curtis, 1992; Wu Neng et al., 1991; Xu Bozhao et al., 1998). Considering the additional benefits of treated bednets, the technology appears to be definitely superior to indoor residual spraying. In places where people are not in the habit of using bednets, they should be motivated to use them.

Treated nets were successfully used in many parts of the world. In India, following the successful trials in Assam and Orissa, the National Malaria Eradication Programme has started large scale introduction of treated bednets in inaccessible areas in the north-eastern states of India (Sharma et al., 1995). During 1995-96 about 17,000 deltamethrin treated nets were distributed in 53 villages in the State of Maharashtra and they have been introduced in tea estates, industries and police force elsewhere in India (Yadav and Sharma, 1997).

Non-usage of bednet is not only due to low affordability, but also due to non-availability at the local market places in the tribal areas and lack of knowledge. The use of bednets depends on many factors like local availability, affordability, cultural preferences, knowledge and experience about the protective benefits. To make them more successful people must be well oriented to accept and utilize them. Formation of village committees consisting of volunteers would produce better results.

Bednets of various qualities are available at reasonable prices in Indian markets. Insecticides should be made available in small sachets and people should be motivated by the health sector and through the mass media to impregnate the nets and use it. Social marketing of impregnated bednets may also be tried.
The development of resistance among vectors to DDT and other insecticides and the human resistance to indoor residual spraying pose a big threat to malaria control programme in India. On top of it environmental pollution and biological accumulation of DDT is well known. No doubt that bio-environmental strategy is cheap, eco-friendly and sustainable, but in places where it is not possible to adopt this method, as in most malarious forested areas in India, impregnated bednets seem to be an effective alternative strategy. When used individually treated nets would provide personal protection to the users, and also possibly to other occupants in the room if used indoors. When used at community level by a majority of people, they would cause a mass killing effect coupled with excito-repellency/deterrency against vector mosquitoes, and would thus reduce the risk of malaria transmission.