Insecticide-treated Nets and Curtains

One of the major innovations in the field of malariology during the past two decades is the development of the technology of insecticide-treated mosquito nets (ITNs). Mosquito nets or curtains have been in use since long in many civilizations including in India. The Italian traveler Marco Polo had mentioned in his travelogue that nobles in southern India used the mosquito curtains made of light cane work in the 13th century AD. Although deliberate treatments on nettings with repellents and even DDT were tried to provide additional protection to individuals against blood sucking insects like mosquitoes. Development of stable pyrethroids during the 1980s led to evaluation of pyrethroid-treated netting and clothing materials against mosquito vectors. Until 1990, several small-scale trials in various countries demonstrated the effectiveness of nets treated with pyrethroids in reducing malaria and vector populations. In China, nets treated with deltamethrin were used on a large-

Steps involved in impregnation of net: (1) measuring the surface of net; (2) measuring the volume of insecticide for impregnation; (3) Impregnation of net; and (4) drying of impregnated net on a plastic sheet

scale during this period. In many endemic countries, laboratory and field trials with untreated and treated mosquito nets were carried out including India.

ITN Trials in Assam

To evaluate effectiveness of mosquito nets in malaria control, the first field trial was carried out successfully in Sonapur PHC, Assam during 1987 to 1991 in areas where *An. minimus* was the main malaria vector (Jana-Kara *et al* 1995 and Sharma *et al* 1996). Cotton nets treated with deltamethrin WP at 25 mg/m^2 were found effective in reducing *An. minimus* population and malaria incidence (Fig. 24). In villages with untreated cotton nets malaria situation remained unchanged, whereas in villages without nets malaria incidence rose significantly during the trial period. General acceptance of nets by the communities was found to be satisfactory.

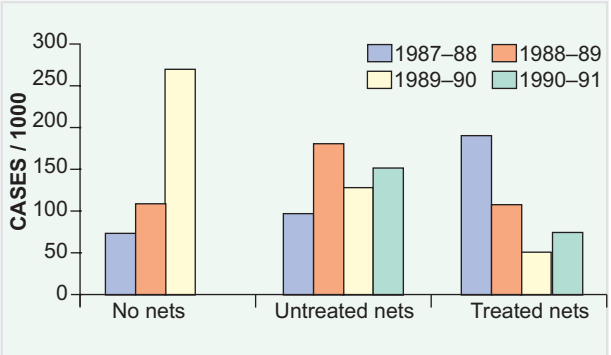

Fig. 24: Impact of untreated nets and deltamethrin-treated nets on malaria in Sonapur PHC, Assam

Another trial comparing efficiency of nylon nets treated with deltamethrin (25 mg/m^2), lambda-cyhalothrin (25 mg/m^2), untreated nets and no nets in villlages in Sonapur, Assam, also showed a superior protection of treated nets over untreated nets or no nets (Fig. 25).

ITN Trials in Orissa

Most of the rural malaria in India is transmitted by *An. culicifacies* in plain areas and in Orissa hill forests by *An. fluviatilis*. A trial was carried out from 1989 to 1994 in areas of north Orissa where above

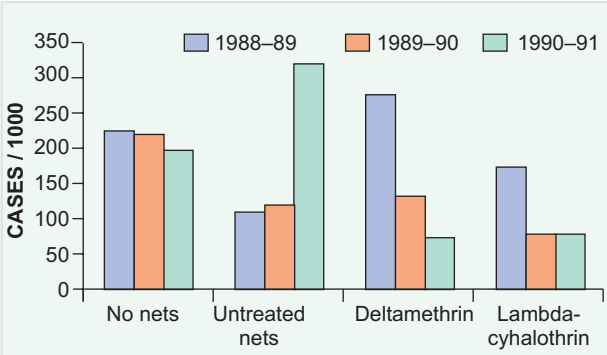

Fig. 25: Impact of untreated nets and nets treated with lambda-cyhalothrin and deltamethrin in another trial in Assam

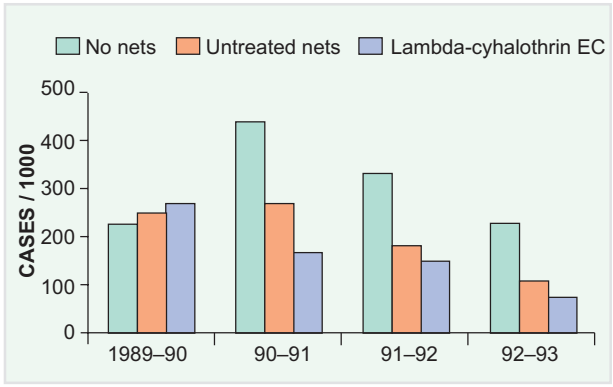

Fig. 26: Impact of lambda-cyhalothrin-treated nets on malaria in villages of Sundargarh district

mentioned two species were the main malaria vectors. In tribal villages of Sundargarh district, nylon nets treated with deltamethrin SC or lambda-cyhalothrin EC at 25 mg/m^2 reduced indoor densities of malaria vectors, *An. culicifacies* and *An. fluviatilis*, their biting rate and the malaria incidence significantly (Figs. 26 and 27) (Sampath *et al* 1998 and Yadav *et al* 1998, 2001).

In the mining areas, where malaria caused tremendous economic loss due to loss in man days, use of cyfluthrin-treated nets resulted in considerable reduction in *An. fluviatilis,* and incidence of malaria (Fig. 28), as well as anaemia and spleen rates in protected children (Sharma and Yadav 1995).

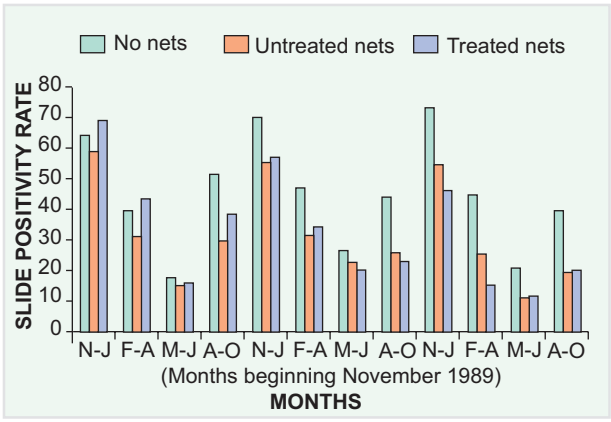

Fig. 27: Impact of deltamethrin-treated nets on malaria in villages of Sundargarh district, Orissa

Hospital occupancy due to malaria in two mining hospitals decreased. Minor communities accepted the treated nets very well and perceived that such nets even reduced other household insect pests besides mosquitoes. Human toxicity studies reported that the treated nets were safe to impregnators and users (Yadav *et al* 1996 and Satpathy *et al* 1997).

Comparative Field Trial with different Pyrethroids and Formulations

A study on the efficacy of impregnated bednets in controlling malaria was conducted from May 1990 to April 1993, covering a population of 6100

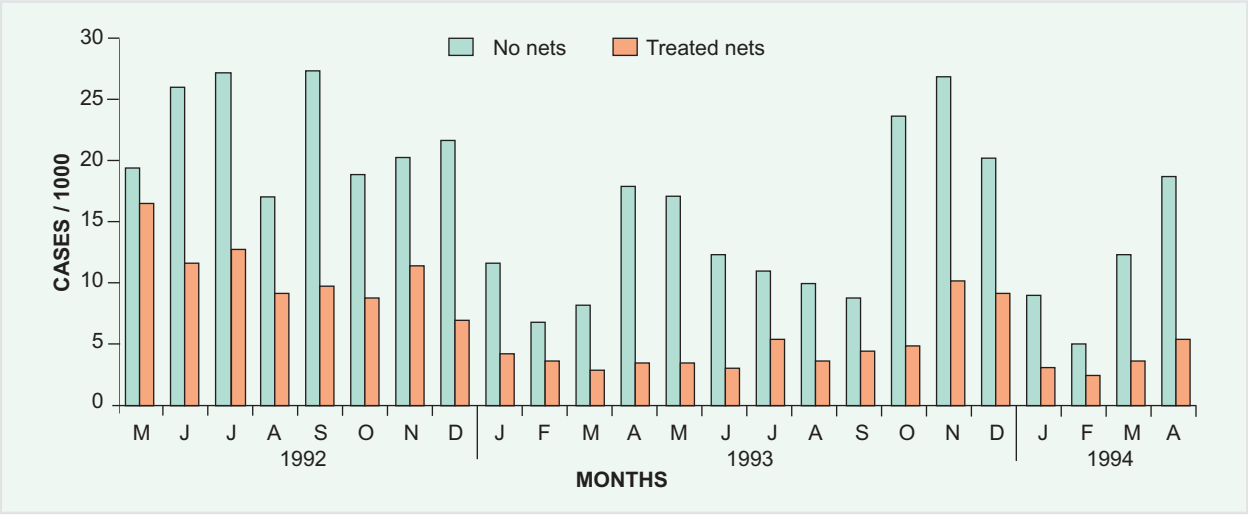

Fig. 28: Efficacy of cyfluthrin-treated nets on malaria in mining settlements, Orissa

in 15 villages of Kuarmunda PHC. The study area was divided into five groups of comparable endemicity. Bednets treated with lambda-cyhalothrin 5% EC (ICON), deltamethrin in 2.5% WP (DM, WP) and deltamethrin 2.5% flow (DM, FLOW) (@ 25 mg/ m^2) were provided to three experimented groups with population of 1220, 1850 and 1100 respectively. The fourth group with a population of 1403 was provided with untreated nets while the fifth group with a population of 814 did not receive nets.

Mosquito densities were monitored fortnightly by hand collection. After first impregnation in May 1990 the density of *An. culicifacies* in ICON treated net area, declined significantly as compared to no net area. The observable impact lasted for nine months. Second impregnation in June 1991 further checked vector density. Based on the results of residual toxicity bioassay six monthly impregnation cycle was scheduled. The impact of DM WP and DM FLOW treated nets on the density of *An. culicifacies* were also similar to that of ICON. However, DM WP treated nets resulted in the itching of skin and the last re-impregnation in the area was carried out with DM FLOW in June1992 (Fig. 29).

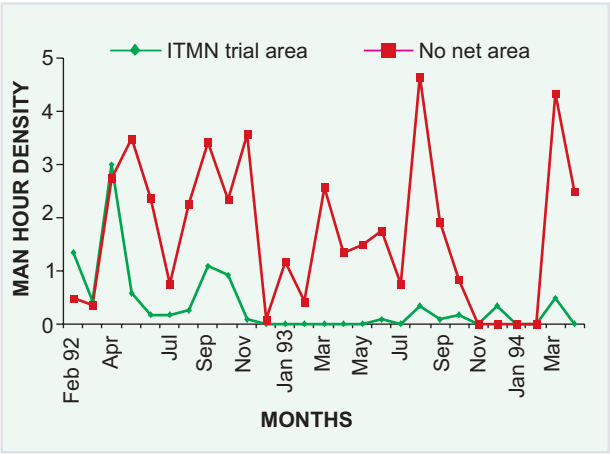

Fig. 29: Impact of insecticide-treated mosquito nets on the density of *An. culicifacies* in the mining area of Sundargarh district, Orissa

During night bite catches (1 night per month for 12 months) using four human baits the total number of vectors (*An. culicifacies* and *An. fluviatilis)* collected were in order of 63 in no net; 19 in untreated net; 12 in DM WP treated net; 11 in DM FLOW treated net; and two in ICON treated net.

In no net area malaria incidence increased from API of 223.6 in the base line year 1992 to 227.3 in the 3rd year of intervention with a considerable increase during the intervening period. The API of the area with untreated nets decreased by 58.5%— from 252.5 to 104.8. The API in the area where ICON treated nets were distributed decreased by 72.5% —from 270.7 to 74.6. DM WP treated nets resulted in a decrease of API from 208.5 to 121.6 (41.8%) after three years of intervention. Nets treated with DM FLOW were provided in November 1990, which resulted in a decrease in API by 59%— from 327.6 to 133.6 after two years of trial. After the completion of the study it was found that haemoglobin levels (g/dl) in children below 10 years of age sleeping under treated nets were higher in children using untreated nets or without nets (DM FLOW 14.9 g/dl > ICON 14.5 g/dl > DM WP 14.3 g/dl > untreated net 11.6 g/dl > no net 11 g/dl). There was also a marked improvement in morbidity of children as the spleen rate dropped by 81% in ICON, 86% in DM FLOW and 90% in DM WP areas, whereas it increased by 35.5% in no net areas.

Bednet Trial in Mining Areas

The mining area of Sundargarh district is hyperendemic for malaria, which is responsible for high morbidity and mortality as well as economic loss. On the request of the authorities of the Rourkela Steel Plant, a bednet trial was conducted in three mining settlements from May 1992 to April 1994. The area is located at an elevation of 700–800 m above the MSL and received annual rainfall of about

2000 mm. The temperature remains favourable for mosquito breeding throughout the year (range 17 to 32°C).

Impregnated nets were provided to a population of 11,762 in three settlements—Tensa, Barsuan and Kalta whereas another three settlements, viz. Toda, Khandadhar and Sasikala with a population of 2920 were kept as control area without net. The nets were treated with cyfluthrin @ 50 mg/m^2 at half yearly intervals starting with April/May 1992. Endemicity of two areas were comparable at the beginning of the study (Parasite incidence—Experimental (E) 8.2, Control (C) 9.7; SPR—E 37.8%, C 21.9%; spleen rate—E 59.3%, C 56.1% and Hb—E 9.9 g/dl, C 11.4 g/dl).

Treated nets caused a considerable reduction in the densities of major malaria vectors, *An. fluviatilis* and *An. culicifacies* as well as the densities of total anophelines and total mosquitoes. Before the distribution of nets, the MHD of *An. fluviatilis* was fluctuating around 5 which was drastically reduced to 0 immediately after the intervention and never exceeded 0.5, that too was occasionally throughout the period of study, whereas in the control area it fluctuated in between 2 and 20. The MHD of *An. culicifacies* also reduced drastically from 4.5 at the beginning of the study to 1 after the distribution of net which was further reduced to 0.2 in the subsequent period. After the second impregnation in November 1992 *An. culicifacies* was totally absent in the hand catches for about six months and found in a very low density in the subsequent period. On the other hand the MHD of *An. culicifacies* remained above 2 in the control area during most part of the study. Besides, treated nets provided total protection from the biting of *An. fluviatilis*.

Epidemiological impact was studied on the basis of fortnightly surveillance. In Tensa and Barsuan areas annual incidence of malaria declined by 68.5 and 69.6% during the I and II year of study respectively, while SPR declined by 25.5 and 27.5% in comparison with the control area (Fig. 30). Similarly, in Kalta area the incidence of malaria was reduced by 11.6% during the first year and 48.7% during the second year compared with the control area. SPR also reduced by 6.2 and 36% in the I and II year respectively.

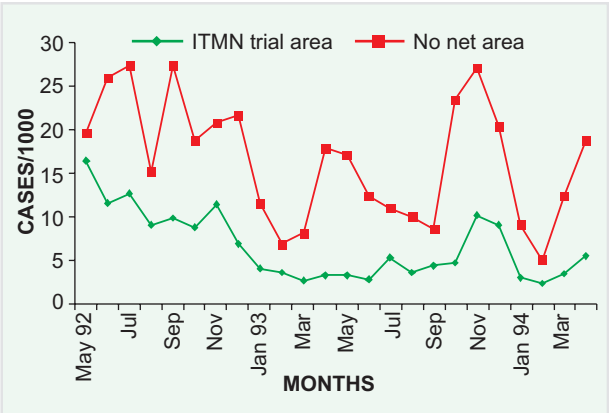

Fig. 30: Impact of ITMNs on malaria incidence in the mining area of Sundargarh district, Orissa

There was a significant reduction in the indoor admissions, due to sever/complicated malaria in the hospitals of Tensa and Kalta. The number of admission in the base line year was 656 which was reduced to 328 in the first year and 170 in the second year of intervention, thereby registering a total decline of 74.1%. During study, no possible toxic effects of cyfluthrin treated bednets were recorded. The compliance of bednet usage was generally good and the trial was well received by the people.

Community Acceptance of Insecticide Treated Mosquito Net (ITN) Trial in a Tribal Population of Keonjhar district, Orissa

A collaborative field trial project under operational research studies was conducted in a tribal area of Jhangira sector in Keonjhar district. The project was financed by Orissa Health Projects, Office of the British Council Division with ODA funds with the objectives to explore whether the communities with poor socio-economic status and living in malaria endemic areas can finance and sustain mosquito net usage and to assess epidemiological impact of the ITN usage.

The duration of the project was from June 1994 to March 1997. The generation of demand for mosquito nets and their subsequent distribution through social marketing at a subsidised price of Rs. 50/- per net was undertaken by CARE-India while NIMR took the responsibility of providing technical support and monitoring the epidemiological impact of the intervention. The distribution of Deltamethrin treated nets (dosage : 25 mg/m^2) commenced from May 1995 in all the 55 villages (population 29000) falling under 7 sections of Janghira sector and a total population of 7799 nets were sold covering approximately 81% of the total population. The nets were re-impregnated at six month interval under the supervision of NIMR.

For epidemiological evaluation, regular entomological and parasitological monitoring was carried out and for comparison a control area of about 22,000 population in the adjoining Jirang sector was selected. The impact was measured on vector densities (Fig. 31), human biting rate, malaria incidence (Fig. 32) and infant mortality rate. The study indicated that treated mosquito nets provide full protection from the bites of mosquitoes and there was 50% reduction in malaria incidence and 34% reduction in infant mortality in experimental area. Surveys conducted to ascertain compliance rate of bednet usage revealed that usage rate ranged from 45 to 60% in different seasons. The trial was well accepted by the people and there was more awareness among the communities to fight against malaria.

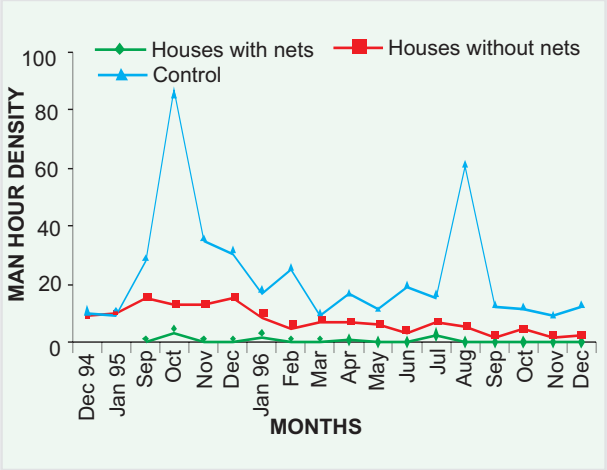

Fig. 31: Impact of insecticide-treated mosquito nets (ITN) on the vector density in Keonjhar district, Orissa

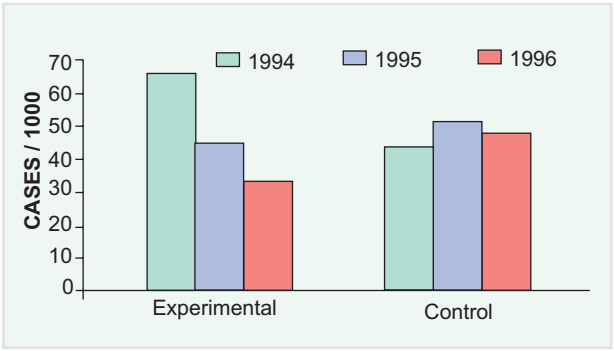

Fig. 32: Malaria incidence in the experimental and control areas of ITN trial in Keonjhar district, Orissa

Evaluation of Mosquito Nets Treated with Deltamethrin Tablet Formulation against Malaria Vectors *An. fluviatilis* and *An. culicifacies* and its Impact on Malaria Transmission

The studies were conducted during 2002–03 in three villages under Bisra PHC of Sundargarh district. These three villages were Birkera (Pop. 506) which was the trial village and village San Pokhari (Pop. 367) and Dudarta (Pop. 271) were control villages. Based on entomological and parasitological parameters, the impact of mosquito nets treated with tablet formulation of deltamethrin was assessed. The bio-efficacy studies showed 100% mortality up to six months in *An. fluviatilis* and 80–100% mortality in *An. culicifacies* up to six months. Therefore, the bio-availability of the insecticide persists on mosquito nets up to six months. The man hour density (MHD) of malaria vectors *An. culicifacies* and *An. fluviatilis* in houses with treated nets was significantly low as compared to houses with untreated nets and no nets. There was overall reduction in entry rates of mosquitoes into the houses with treated nets compared to other two control villages with untreated nets and no nets. There was 39.6% immediate mortality in mosquitoes coming in contact with treated nets and 43.3% of mosquitoes succumb to lethal dose within 24 hours. The low feeding success rate of mosquitoes in the trial village in comparison to villages with untreated net and no net also confirm efficacy of tablet formulation of deltamethrin. The insecticide formulation was found to have low excito-repellency rate for both the vector species, which is likely to produce a better mass killing effect on the mosquito population. There was significant reduction in malaria incidence in the trial village in comparison to control villages with plain nets and no nets. Cross-sectional malaria prevalence data collected during pre-intervention and intervention period also showed that there was 65.2% reduction in malaria parasite rate (Fig. 33) in the population using treated nets, which is significantly higher in comparison to the population using untreated nets (35.4%) and no net (7.5%).

Data on splenomegaly and parasite prevalence in 2–9 years children are given in Table 1. Baseline data collected during December 2002 showed no significant difference in spleen rates in children from all three villages ($\chi^2 = 0.2$, Df-2, $p > 0.05$). At the end of one year of intervention in December 2003, the spleen rate in children using treated net showed significant reduction (χ^2=15.4, Df-1, $p<0.001$). The reduction in spleen rate in children using untreated net was also significant (χ^2=9, Df-1, $p<0.005$), whereas the spleen rate was found higher in children using no net, in comparison to baseline data although the increase in spleen rate was insignificant (χ^2=0.6, Df-1, $p>0.05$). Parasite rate in children 2–9 years showed no significant change between baseline and after one year data in the population using no nets (χ^2=0.8, Df-1, $p >0.05$) but significant reductions were observed in population using untreated net (χ^2=5.2, Df-1, $p <0.025$) and treated nets (χ^2=12.2, Df-1, $p <0.001$). The study showed that in areas with persistent malaria throughout the year such as Sundargarh district, two treatments of mosquito nets at an interval of six months would provide effective protection against malaria.

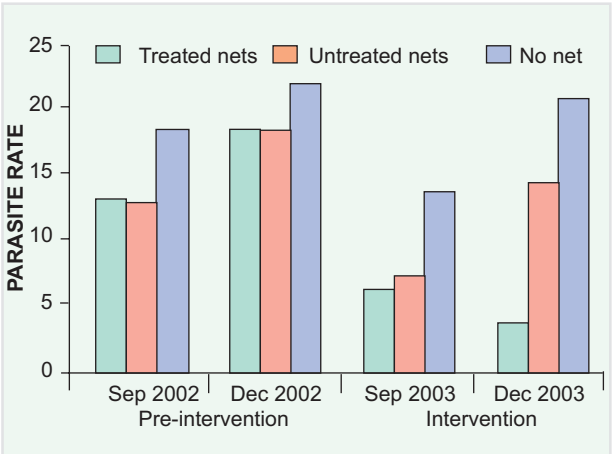

Fig. 33: Malaria prevalence in the study villages with K-O TAB treated nets, untreated nets and no net as recorded through cross-sectional point prevalence surveys conducted in September and December during pre-intervention and intervention phases

Table 1. Impact of use of treated mosquito nets on splenomegaly and child parasite rate (CPR) in children aged 2–9 years, as recorded through cross-sectional surveys conducted in pre-intervention (December 2002) and post-intervention (December 2003)

Population using	Year	n	Spleen rate (%)	χ^2	AES	CPR (%)	χ^2
Treated net	2002	41	63.4	1.54	36.6		
	2003	47	12.7	15.4 ($p<0.001$)	1.12	10.6	2.2 ($p<0.001$)
Untreated net	2002	35	69.6	1.9	42.8		
	2003	42	20.7	9.0 ($p<0.005$)	1.0	19.0	5.2 ($p<0.025$)
No net	2002	37	59.5	1.64	37.8		
	2003	39	74.3	0.6 NS	1.43	28.2	0.8 NS

NS: Not significant; AES: Average enlarged spleen; *Chi-square test was applied to test the significance of difference between data collected at baseline and after one year of intervention.

Phase III Evaluation of High Density Polyethylene (HDPE) Mosquito Nets Treated with Insecticide

A field trial was completed on the efficacy of High Density Polyethylene (HDPE) bednets indigenously manufactured by small scale industries in Tamil Nadu. The nets were treated with deltamethrin flow at a dosage of 25 mg/m^2 and were evaluated against malaria vectors, *An. culicifacies* and *An. fluviatilis* as well as its impact on malaria transmission in one of the highly endemic areas of Orissa. The study was sponsored by NVBDCP. The trial was conducted in Kuarmunda and Bisra blocks of Sundargarh district. The study area comprised 13 villages which were randomized into three clusters and designated as treated net cluster (4 villages 2069 pop.), untreated net cluster (4 villages 1859 pop.) and no net cluster (5 villages 1863 pop.). Baseline pre-intervention data were collected from December 2006 to February 2007 followed by three months of intervention phase from March to May 2007. Baseline studies showed that both the vector species *An. culicifacies* and *An. fluviatilis* were 100% susceptible to deltamethrin. Bioassays conducted on treated HDPE nets after 4th washing resulted in reduced mortality of 35 and 57.5% in *An. culicifacies* and *An. fluviatilis* respectively. The median knock-down time for these species during the first month of intervention (March, 2007) was 4.30 and 4.25 min respectively and after 3 months of use, the median knock down time for these vector species was 4.55 and 4.30 respectively. In treated HDPE net area, there was a significant reduction of 83 and 89% in the entry rate of *An. culicifacies,* and *An. fluviatilis* with an over all reduction of 51.0% in total mosquitoes in comparison to pre-intervention phase ($p<0.05$). Floor sheet collections in houses with treated net indicated 29% immediate mortality in total mosquitoes. The overall feeding success rate of mosquitoes in the trial village was only 17.7% in comparison to 35.7 and 76% in villages with untreated nets and no nets respectively. A significant reduction of 87 and 100% was recorded in parity rate and human blood index of vector species in deltamethrin treated HDPE net area respectively. During intervention phase, there was a reduction of 63 and 50% in malaria incidence in treated net and untreated net areas respectively. However, no significant reduction was recorded in control villages without nets ($p>0.05$). The community acceptance of HDPE nets was high as there was 85–99% compliance rate of net usage in the study population during different months. The treated HDPE nets provided relief not only from mosquitoes but also from other household pests. The HDPE nets were found to be safe for human and no adverse events were reported either by the users or net impregnators.

ITN Trials in Madhya Pradesh

Simultaneously during the years 1989–91 another trial conducted in some tribal villages of Mandla district in Madhya Pradesh, where *An. culicifacies* and *An. fluviatilis* are malaria vectors, showed a low impact of treated nets. The reasons for low impact were poor compliance by inhabitants due to their varied socioeconomic status and means of livelihood. Later, another trial in the villages of Jabalpur district, however, showed a marginally better efficacy of cyfluthrin-treated nets over routine or supervised spraying of DDT indoors.

Comparative Efficacy of ITN and IRS in Karnataka

A study was carried out in PHC Kanakatte, District Hassan, Karnataka during the years 1995–2001. During the year 1995, baseline data were collected. Cyfluthrin impregnated mosquito nets @30 mg/m^2 were distributed to inhabitants in seven villages in 1996. Compliance for the usage of bednets was ensured by imparting health education.

First impregnation was made by villagers under NIMR supervision in March 1996 and subsequent re-impregnations were made in November 1996,

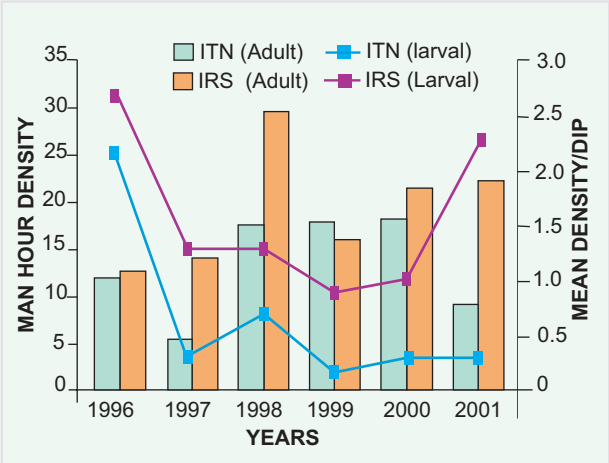

Fig. 34: Comparative efficacy of ITN and IRS with cyfluthrin on adult and larval densities

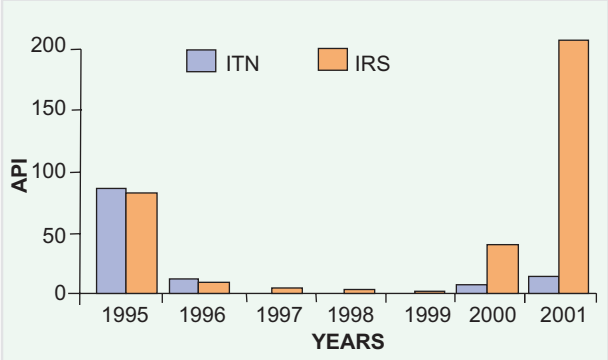

Fig. 35: Comparative efficacy of ITN and IRS with cyfluthrin on malaria incidence

May 1997 and December 1997 respectively. Entomological evaluations were done by NIMR at regular intervals during the intervention period. Malaria surveillance was carried out by the State Health Department. PHC, Belagur, District Chitradurga, Karnataka was under IRS with cyfluthrin. Comparative efficacy of ITN and IRS areas was studied for these two areas.

It was observed that adult and larval densities of *An. culicifacies* (vector mosquito) were low in areas with intervention of ITN (Fig. 34). The results of the five year study indicated substantial decrease in malaria incidence in ITN area as compared to area with IRS (Fig. 35). During the years 1996–98, in both bednet and IRS areas there was decrease in malaria incidence compared to 1995. It was observed that during the years 1999–2001, the malaria incidence in IRS areas in the absence of indoor spray increased substantially, while in ITN areas the incidence remained low even with the use of bednets without further re-impregnation after 1998.

ITN Trials in Ghaziabad

The relative efficacy of insecticide-treated mosquito nets was evaluated under field conditions in Dehra village of Dhaulana PHC, District Ghaziabad (Uttar Pradesh), India during 1996. Nylon nets were impregnated with deltamethrin, cyfluthrin, lambda-cyhalothrin and etofenprox at 25 mg/m^2 by standard methods. Repellency and excito-repellency, killing and airborne actions were monitored from dusk-to-dawn by hourly collection of mosquitoes that entered and rested in rooms and also females that landed on treated and untreated mosquito nets. Results revealed 15.3–22.9% repellent action, 98.3–99.3% excito-repellency action and 100% mortality of females that landed on treated fabrics (Ansari and Razdan 2000). No significant differences were observed in the efficacy of different synthetic pyrethroids against anophelines. However, against *Cx. quinquefasciatus* Say there was a significant difference between deltamethrin and etofenprox. Control of anophelines was more pronounced than *Cx. quinquefasciatus*. There was no pronounced airborne action with any insecticide tested. Synthetic pyrethroids with strong airborne action may be more

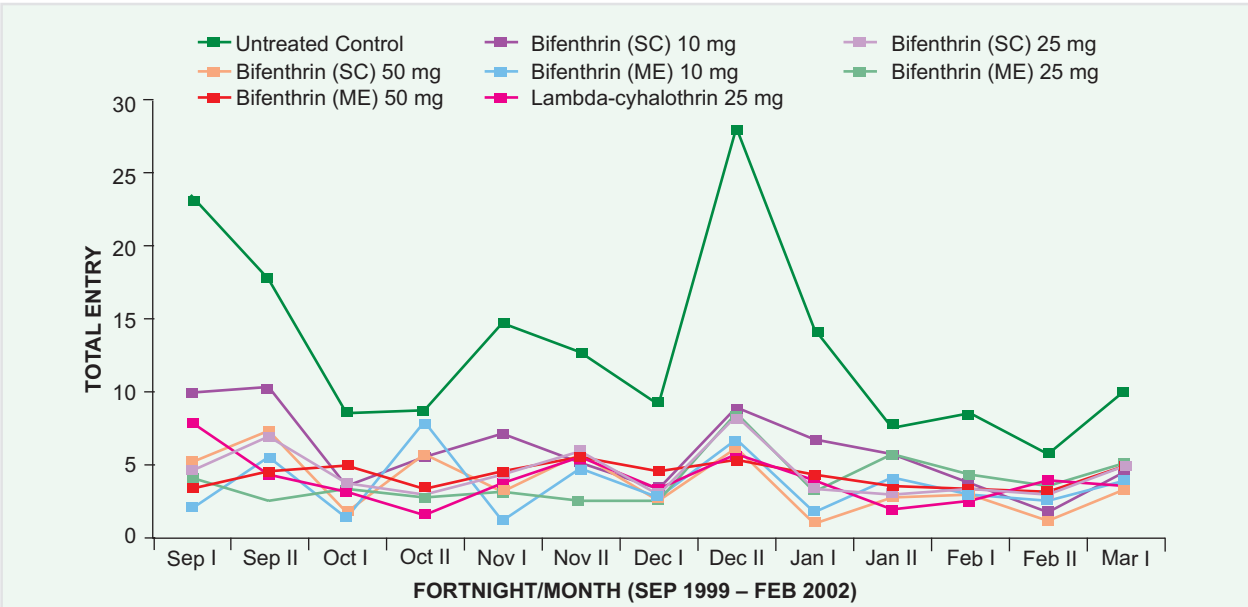

Fig. 36: Total entry of mosquitoes into the habitats in different months during the intervention period

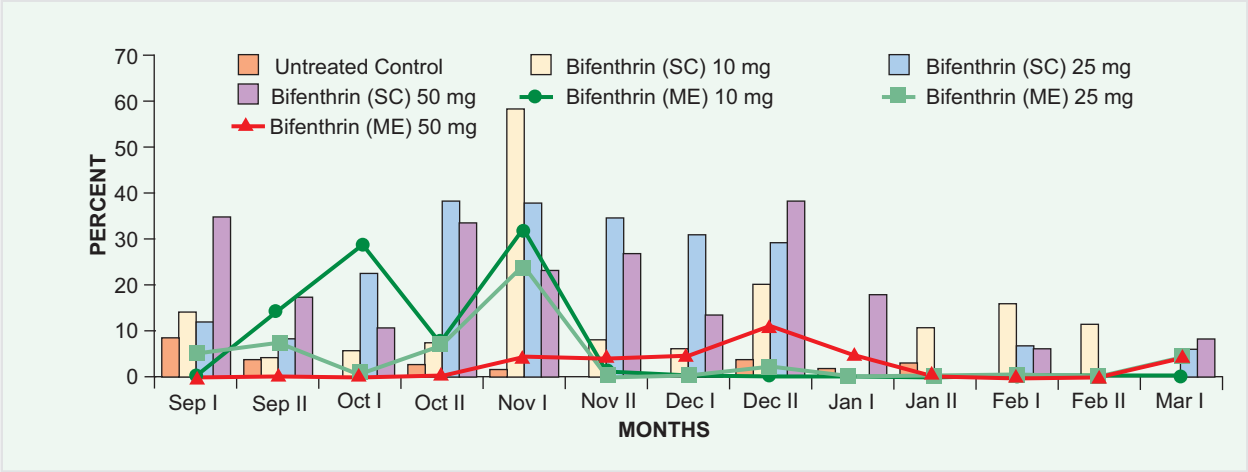

Fig. 37: Excito-repellency rates in the mosquitoes with different doses and formulations of bifenthrin

appropriate for impregnation of mosquito nets.

ITN Trials in Haryana

A field trial was carried out in the year 2000 in villages of District Sonepat, Haryana to assess the efficacy of bifenthrin as an impregnant on mosquito nets. Phase II trial was conducted to assess the comparative efficacy between two formulations, namely suspension concentrate and micro-emulsion. Efficacy was studied for both the formulations at three doses of impregnation, 10, 25 and 50 mg/m^2. Net bioassays to assess the persistence indicated bioavailability up to 11 fortnights (~ 5 months) at all the doses of the two formulations. There was an estimated 50% reduction in the entry of the mosquitoes into the houses with intervention of treated nets compared to the houses without treated nets indicating the impact of the insecticide (Fig. 36). The excito-repellency rates in the mosquito were low in houses with nets impregnated with ME formulations and was marginally higher than the houses with non-impregnated nets. These results indicated increased human-mosquito contact in intervention with ME formulations (Fig. 37). Uniform bio-availability of the insecticide on nets was observed with all the doses of the two formulations including the ME formulation and in view of the increased excito-repellency rates with this formulation, Bifenthrin ME formulation was suggested for impregnation @ 10 mg/m^2. for future use.

Efficacy of Water Dispersible Deltamethrin Tablets for Treatment of Individual Nets of Different Fabrics

Deltamethrin water dispersible tablets (K-O TAB®) offer operational advantages and ease in use over the liquid formulations of pyrethroids. K-O Tab were evaluated for bio-efficacy and persistence on different fabrics, namely cotton, nylon and polyester nets against malaria vectors *An. culicifacies* and *An. stephensi* in Kheda, Gujarat during 2001–02. Mosquito nets treated @ 25 mg/m^2 were distributed in three villages, during June and July 2001. Both treated and untreated nets were distributed in three villages. A set of 4 nets (2 each treated and untreated) of each fabric was kept in the laboratory for evaluation of shelf life of treated nets. Cone bioassays were carried out at monthly interval using laboratory reared *An. culicifacies* and *An. stephensi* by exposing to the treated surface for 3 minutes. Impact of washing frequency on the efficacy and persistence of insecticide on different types of fabrics, at first wash at one-month and second wash at three months interval was studied.

In cone bioassays on cotton and polyester nets, distributed for field use indicated more tolerance in *An. stephensi* as compared to *An. culicifacies*. Bioassays on unwashed field used cotton, nylon and polyester nets registered 100% mortality in *An. culicifacies* up to four months after the treatment (Fig. 38) and in *An. stephensi* mortality ranged from 90–100% till that period (Fig. 39). Bioassays on unwashed cotton, nylon and polyester nets, five months after the treatment, produced 75, 91.7 and 83.3% mortality in *An. stephensi* and 83.9, 83.3 and 100% mortality in *An. culicifacies,* respectively.

Bioassays of *An. stephensi* on cotton nets washed once and twice produced 40 and 55% mortality respectively as against 75% mortality on unwashed nets after five months of treatment. Similarly, mortalities on washed polyester nets were

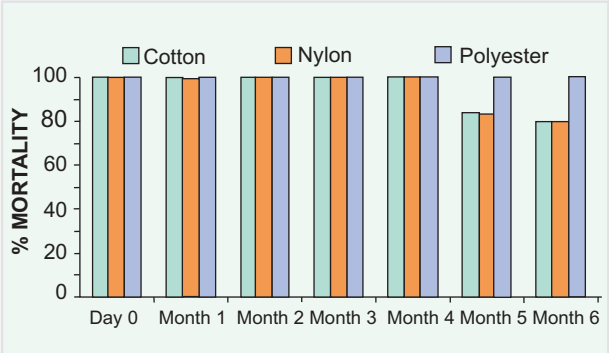

Fig. 38: Bioassay of K-O TAB treated nets on *An. culicifacies*

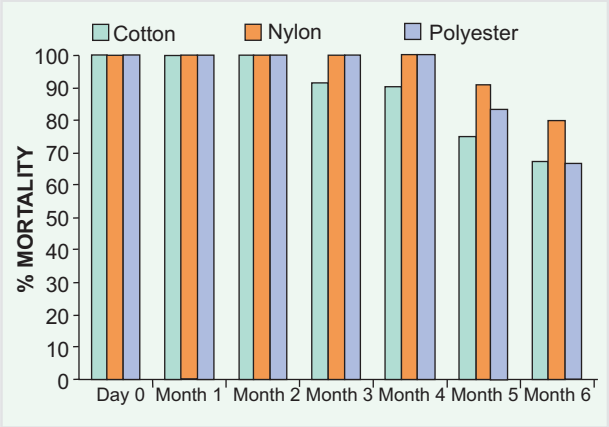

Fig. 39: Bioassays of K-O TAB treated nets on *An. stephensi*

70% (1 wash) and 66.7% (2 washes) as against 83.3% on unwashed nets. Contrary to this, bioassays on nylon nets washed once and twice produced less mortality in *An. stephensi* (93.3 and 86.7% respectively) than in *An. culicifacies* (73.3 and 76.7% respectively). Washing had no significant impact on efficacy against *An. culicifacies* exposed to cotton nets; washed once (81.7%) and twice (80%), and to polyester nets washed once (100%) and twice (75%). Thus K-O Tab would help ensure a better community acceptability and sustainability.

Evaluation of Operational Programme of ITNs

In 2003, NVBDCP initiated a pilot project on insecticidal treatment of community owned nets in 15 malaria endemic districts in 11 States. The project used public-private partnership where insecticide manufacturers would make available commercial packs of insecticide and community would pay for the cost of insecticide. Certain NGOs were involved for social mobilization towards promotion of use of bed nets and their treatment with insecticide. IEC activities were carried out in all the areas to promote the use and acceptance of ITNs. A survey in these 15 districts indicated presence of large number of mosquito nets owned by community, of which a great majority were treated under the pilot project. The project has been relatively more successful in the north-eastern states where communities use nets traditionally. In Darrang 37% of the available nets, in Karbi-anglong 45% nets and in West Aizwal 46% of the targeted number of nets could be treated. In Anand district, Gujarat state, 25% of 55,000 nets in 1.9 million population could be treated. The manufacturer had made the deltamethrin flow available at the district level. Communities were found willing to procure insecticide from the health authorities. Training of community volunteers and health workers has helped in capacity building for treatment of bed nets on an ongoing basis. Household surveys conducted by NIMR in districts of Anand in Gujarat, Betul in Madhya Pradesh, Ranchi and East Singhbhum in Jharkhand, Kanker in Chhattisgarh and Keonjhar in Orissa reported that the ITN programme was largely successful in areas where proper IEC and training motivated the local communities before initiating it (Yadav and Bhatt 2004; Batra *et al* 2004a,b; Bhatt and Gupta 2004). Where communities were not well informed, the programme couldn't take off, such as in Betul. In Anand, nearly 40% children under 5 years had access to a net/ITN (Yadav and Bhatt 2004).

Sustainability of ITNs

The efficacy of ITNs against malaria transmitted by local mosquito vectors in many areas has been proved in field by NIMR, but the question of sustainability needs to be addressed (Yadav and Sharma 1997). A field project in collaboration with British Council Division (U.K.) and M/s. CARE India was undertaken in Keonjhar, Orissa in 1994 (Yadav 1997). The project showed that it was possible to promote purchase and use of treated nets by community financing (sale of nets). The National Anti Malaria Programme adopted the ITN-technology and distributed ITNs in north-eastern states. These are now being promoted through the state antimalaria programmes of different states and this constituted a major advancement in vector and malaria control. Also, in National Anti Malaria Programme's Enhanced Malaria Control Project being implemented in 100 districts in eight states, sustainability of ITNs was evaluated.

In considering sustainability, distinction needs to be made between programme sustainability from the managers' point of view, which is restricted to the programme cycle and overall sustainability of ITNs as a component of the antimalaria strategy. While sustainability is not easy to define or measure, three main indicators that could be used are: proportion of population using or willing to use ITNs; proportion of ITNs actually retreated; and decreased reliance on single-source external intervention and shift towards a greater community ownership/participation. Thus, sustainability of an ITN programme will depend upon various factors such as the acceptability, feasibility, affordability, technical support requirements, production, sale and distribution systems of nets.

Relative Efficacy of Insecticide-treated Curtains (ITCs) against Mosquitoes under Laboratory Conditions

The relative efficacy of pyrethroid-impregnated fabrics was evaluated against *An. stephensi*, *Aedes aegypti* and *Cx. quinquefasciatus* under laboratory conditions (Ansari *et al* 1998). Results revealed that deltamethrin (D) was significantly superior in comparison to lambda-cyhalothrin (L) and cyfluthrin (C). Results of bioassay tests and relative toxicity index (RTI) revealed that deltamethrin was 1.5 and 1.9 times more effective than lambda-cyhalothrin and cyfluthrin, respectively, against *An. stephensi* exposed to cotton fabric treated at 100 g/m^2. Similarly, deltamethrin was 3.9 and 4.6 times more effective

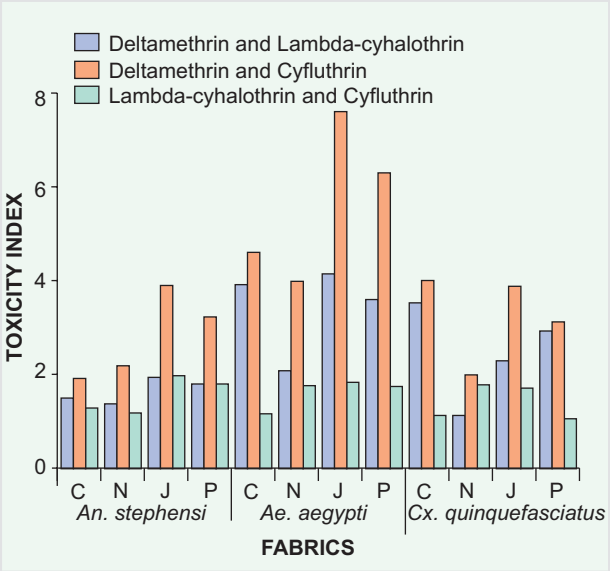

Fig. 40: Relative toxicity indices on different fabrics (C: Cotton, N: Nylon; J: Jute; and P: Polyethylene)

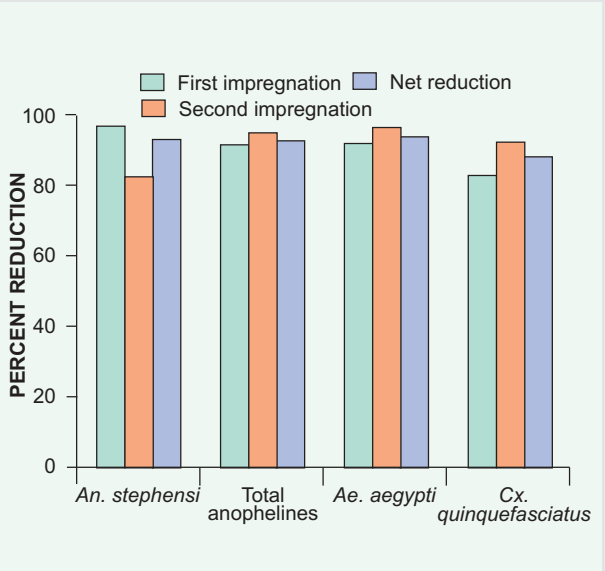

Fig. 41: Mean reduction of adult densities of mosquitoes in deltamethrin-treated curtain area, Moti Bagh, New Delhi

than lambda-cyhalothrin and cyfluthrin respectively against *Ae. aegypti* and 3.5 and 4.0 times more effective against *Cx. quinquefasciatus* respectively. Of the four fabrics—cotton, nylon, polyethylene and jute, cotton was the best on the basis of median lethal dose (LD_{50}) and 90% lethal dose (LD_{90}) values and persistence of insecticide (Fig. 40).

ITC Trials in Delhi

A field trial in an area in New Delhi Municipal Committee to demonstrate composite control of *An. stephensi* and *Ae. aegypti* by spraying deltamethrin at 100 mg/m^2 on window and door curtains of habitations showed 88–93% reduction of the vector species in the experimental area (Fig. 41) (Ansari and Razdan 2001). The impact of deltamethrin-treated curtains was also evident against non-target species (67.9–85.7%; $p<0.05$). Treated curtains provided 100% kill of *Anopheles stephensi* and *Ae. aegypti* for 3–4 months, followed by a gradual decline in successive months. Use of deltamethrin-treated curtains resulted in 92% reduction in SPR and 95.4% reduction in malaria cases/1000 population. The cost of deltamethrin treatment was less than per house per annum. Insecticide-treated mosquito window and door curtains, along with legislative measures, may provide cost-effective concurrent control of mosquitoes and other domestic pests.

ITC Trials in District Ghaziabad (U.P.)

In selected villages of District Ghaziabad, operational feasibility and efficacy of hessian curtains impregnated with deltamethrin @ 100 mg/m^2 was evaluated in comparison to indoor residual spraying of HCH @ 0.2 g/m^2. The impregnation was carried out before the onset of transmission and observations were continued up to two transmission periods. District Health Authorities sprayed HCH indoors. There was 87% reduction of *An. culicifacies* up to six months and 61.6% reduction in total mosquitoes in comparison to HCH indoor residual spraying (Ansari and Razdan 2000). Follow-up studies revealed that the impact of deltamethrin impregnated curtains declined after 6–7 months. The results of bioassay tests revealed 100% mortality up to 6–7 months. Epidemiological evaluation revealed 81.9% reduction in total malaria cases as against 88.5% in *P. falciparum* cases. Similar reduction was also observed when slide positivity rate (SPR), slide falciparum rate (SFR), cases/1000 and *Pf*/1000 were compared to corresponding village. Pilot studies have indicated to evaluate the efficacy of impregnated curtains on a large-scale as these are relatively cheaper than the conventional vector control method—insecticide residual spraying.

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