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BIOENVIRONMENTAL CONTROL OF INDUSTRIAL MALARIA AT BHARAT HEAVY ELECTRICALS LTD., HARDWAR, INDIA—RESULTS OF A NINE-YEAR STUDY (1987–95)

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ABSTRACT. A bioenvironmental model to control malaria at Bharat Heavy Electricals Ltd. in Hardwar was developed by using existing resources to reduce mosquito breeding. The civil maintenance department carried out major source reduction work by filling pits, low lying areas, ditches, etc., with fly ash from a coal-fired power station, construction of stand posts and proper drainage, mosquito proofing of overhead tanks, and preventive maintenance of the water supply and the sewage system. The project staff has applied 1) expanded polystyrene beads to underground tanks, leaking sluice valve chambers, and blocked sewage manholes; 2) biolarvicides to water accumulated in factory scraps, blocked drains, and riverbed pools, and 3) larvivorous fish to storm water drains, effluent ponds, and drains for the effective control of mosquito breeding. Improved surveillance and treatment coupled with comprehensive developmental schemes were additional tools to gain community support. As a result of intervention measures, the vector density in the township was significantly lowered compared to that of a control area, and there was a drastic reduction in malaria incidence compared to that of the preintervention year: only 190 cases were recorded in 1995, compared to 3,049 cases in 1985. The study has shown that malaria control in an industrial township through an integrated control approach is practical, sustainable, and economically feasible and reduces insecticide pollution in the environment.

INTRODUCTION

Malaria control in industrial complexes in India is carried out by the government, and in some cases, industries may provide additional staff and hospital infrastructure for antimalaria work. The strategies consist of application of larvicides using Abate®, fenthion or oil as larvicides, thermal fogging with malathion and residual spraying with DDT, HCH or malathion, as adulticides, passive case detection and treatment, etc. Malaria control in industrial areas is problematic not only because of poorly conducted antimalaria operations, but also because of malaria imported by a migratory population that contracts infection in endemic areas and brings it into industrial areas.

Development of insecticide resistance in vector populations and concern about possible environmental pollution have created serious impediments in the fight against malaria using residual insecticides. An alternative approach is to control malaria vectors by bioenvironmental methods, i.e., the integration of biological control methods and environmental modification and management. This strategy was conceived many decades ago and should be considered as a holistic approach to malaria control on a sustainable basis, incorporating environmental-improvement and income-generating schemes (Sharma 1987). The strategy was implemented in one of India's foremost public-sector industrial complexes, Bharat Heavy Electricals Limited (BHEL) in Hardwar (Uttar Pradesh) in July 1986. Environmental modification and manipulation methods combined with prompt case detection and radical treatment were demonstrated to successfully control indigenous malaria transmission at the BHEL township over a 1-yr period (Dua et al. 1988). The results of a 9-yr longitudinal study on bioenvironmental control of industrial malaria at BHEL Hardwar is presented in this paper to examine the long-term impact of the strategy.

MATERIALS AND METHODS

Study Area

Bharat Heavy Electricals Ltd. Hardwar manufactures heavy electrical equipment used in power generation plants, and its annual turnover is US $100 million. It is spread over an area of 25 km^2 and is situated southwest of Hardwar between 78°9′ and 78°22′E and 29°57′ and 30°18′N. The terrain is composed of foothills of the Shivalik range. The average rainfall is 1,200 mm, and minimum and maximum temperatures are 5°C and 42°C, with average relative humidity 50–95%. On the BHEL site are located a main industrial complex and several ancillary units, and 8 planned and 7 unauthorized low-income residential areas. The medical facilities available include a 180-bed hospital and 6 dispensaries in the residential areas. The total population of the site was 45,000 in the 1981 census, rising to 70,000 in the 1991 census. About 10% of the total population lives in temporary thatched huts in the labor colonies. A control area with a population of 3,000 was selected 5 km away from the BHEL township for comparison. The control area was in close proximity to small industrial units of Uttar Pradesh Industrial Development Corporation. The habitats of *Anopheles culicifacies, An. fluviatilis,* and *An. stephensi* were similar to those at BHEL and malaria intervention measures using insecticides were applied by the National Malaria Eradication Programme (NMEP). Malaria cases registered annually at BHEL hospital from 1983 to 1986

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Table 1. Intervention strategy adopted at the BHEL complex.

Problems	Methodology
Large ditches/borrow pits/low-lying areas	Filling with coal-fired power station fly ash
Water stagnation around community taps	Construction of cemented stand pipes and proper drainage of wastewater
Domestic wastewater	Construction of soakage pits
Water stagnation in earth drains	Construction of cemented drains with an adequate gradient to ensure water flow
Uncovered overhead tanks	Mosquito-proofing with proper covers
Small underground tanks/sluice valves	Application of expanded polystyrene beads to chambers and choked manholes
Blocked open small drains	Desilting and canalization
Storm water drains and large underground tanks	Introduction of larvivorous fish *Poecilia* and *Gambusia*
Domestic containers	Emptying at weekly intervals
Fever cases	Early case detection and administration of radical treatment within 24 h

were 1,129, 1,623, 3,049, and 2,733 respectively. These figures include an increasing number of *Plasmodium falciparum* cases resulting in serious sickness and complications, and a few malaria-caused deaths were also recorded. Failure of chloroquine therapy in some patients was reported by some physicians. The consumption of antimalarial drugs was very high in comparison to reported malaria cases, because many cases were treated on the basis of clinical symptoms without blood slide confirmation and are thereby not included in the reported cases. Apart from human suffering due to malaria, 15% of the total hospital budget was spent on malaria control. It was considered to have caused considerable loss in industrial production.

Mosquito breeding potential: The anopheline and culicine populations on the site were very high. The breeding sites, both natural and manmade, included seasonal rivers and streams, large numbers of borrow pits, ditches, low-lying areas, improperly disposed stagnant wastewater, open and blocked drains, overhead tanks, underground tanks, effluent ponds, ornamental tanks, factory and domestic waste such as discarded tins, tyres, and desert coolers, etc. Before launching the intervention strategy, all potential mosquito breeding habitats were mapped, and an action program for specific situations was planned.

Intervention Strategy

Intervention was started in September 1986, and by January 1987, the entire site was brought under bioenvironmental control. The specific components of this intervention strategy are given in Table 1. It aimed to use the existing infrastructure of BHEL by involving the civil maintenance, water supply and sewerage, medical, and publicity departments, as well as the local community, in vector control. The following antivector measures were integrated to control malaria under this strategy.

Source reduction: The BHEL thermal power station produces an estimated 100 m^3 of fly ash per day and about US $40,000 are spent annually for its disposal. This fly ash was used for filling of borrow-pits, ditches, and other low-lying areas. The factory civil maintenance department that was responsible for disposal of the fly ash was instructed to direct their contractors to dump fly ash in specified mosquito breeding sites under the supervision of project staff. A front-mounted dozer tractor was used to level the land. An army bulldozer was requisitioned for spreading fly ash and leveling about 1,000 ha of land that had been a major mosquito production site during monsoons.

Drainage: Wastewater from community taps located in the low-lying areas in the low-income residential area had been stagnating. These water taps were removed and repositioned in the form of community stand pipes at raised platforms so that wastewater could drain away. Similarly, leaking pipes had led to accumulation of water, allowing vector breeding, and choked manholes had been a major source of culicine mosquito production. All such faults were regularly monitored by project staff and rectified by the water supply and sewerage department of BHEL.

Application of expanded polystyrene (EPS) beads: Expanded polystyrene (EPS) beads were applied at 100 g/m^2, controlling mosquito breeding in leaking sluice valve chambers where *An. culicifacies* and *An. stephensi* had been breeding extensively. Similarly, EPS beads were used in open blocked manholes for controlling *Culex* mosquitoes.

Biological control: Larvivorous fish and bacterial larvicides were used in habitats where source reduction methods could not be applied.

a) Use of fish. *Poecilia reticulata* and *Gambusia affinis* were mass produced in natural ponds in the BHEL complex. The fish were introduced into drains, underground tanks, ornamental tanks, and effluent ponds.

b) Use of biolarvicides. The bacterial larvicides

Bactoculicide® (*Bacillus thuringiensis israelensis*) and Spherix® (*B. sphaericus*) were used to control mosquito breeding in a variety of habitats in the township and factory areas. One of the major breeding sites on the BHEL site was water accumulated in large amounts of industrial waste such as broken heavy machine parts, iron moulds, and discarded drums where *Aedes* and *Culex* were breeding together with a small percentage of *Anopheles* mosquitoes. Bactoculicide water dispersible formulation was applied at 0.5 g/m^2 in industrial scraps (Dua et al. 1993). Spherix was applied at a dosage of 1 g/m^2 in riverbed pools, stagnant drains, and rainwater collections.

Health education and community participation: Emphasis was laid on involving the local community in the vector control program. This was achieved through health education. The target population was identified and door to door visits were made on a regular basis. Health camps and group meetings were organized to educate people about mosquitoes, malaria, and methods of personal protection. Health education through charts, folders, exhibitions, and live materials proved useful in motivating the communities. Health education camps were organized in the schools to impart health information to school children. A feeling of self-reliance and collective responsibility was created among the people so that it was possible to organize *Shram dan* (voluntary labor camps) for source reduction work in low-income residential areas. Health committees were formed among local residents to maintain the responsibility of looking after the sanitary conditions in and around the residential areas.

Intersectoral coordination: Close cooperation with various departments of BHEL helped in the operation of the malaria control project. For example, the civil maintenance department carried out major source reduction work through filling pits with industrial waste, construction of stand pipes and proper drainage around them, mosquito proofing of overhead tanks and preventive maintenance of the water supply and sewerage system. The medical and publicity departments provided support for the program. Other government agencies, such as Social Forestry, the Indian Army, the Nonconventional Energy Development Agency, and the Rural Development Centre, provided additional support for developmental activities during the course of the project (Dua and Sharma 1994b).

Environmental improvement: Areas reclaimed through filling were converted into parks and playgrounds. Eucalyptus and a variety of other trees were planted. Smokeless wood stoves and flush improvised latrines were installed in low-income areas as part of environmental improvement schemes for which technical advice and assistance from other government departments was solicited.

Surveys

The following entomological and parasitological surveys were carried out from September 1986 onward.

Entomological surveys: Indoor resting adult mosquito densities were monitored by searches with flashlight and aspirator in 5 parts of the intervention areas and 1 control area at fortnightly intervals. These collections were carried out between 0600 and 0800 hr from 3 human dwellings and 3 cattle sheds at each indicator site in the experimental area and the control area. Mosquitoes from each dwelling were kept separately in test tubes and identified. Densities per man-hour of searching of total anophelines and vector species were calculated. Weekly peridomestic and intradomestic larval surveys were conducted, and positive larval habitats were subjected to intervention measures in the experimental area, while intervention measures in the control area were taken by a state malaria unit.

Parasitological Surveys: Weekly active surveillance was organized by the project staff to detect all fever cases through house-to-house visits in all the low-income residential areas. Fever cases from high-income areas were monitored for malaria through passive surveillance of patients reporting to BHEL hospital. Surveillance in the control area was not possible due to practical limitations. All slides were brought to the project malaria clinic, Jaswant Singh and Bhattacharjee (JSB)-stained, and examined on the day of collection. Radical treatment was provided to all malaria cases within 24 hr by project staff. No presumptive treatment was given except in the emergency patients; instead, an antipyretic drug was given until a slide diagnosis was available. *Plasmodium vivax* malaria cases were treated with 900 mg chloroquine in divided doses (D0-600 mg; D1-300 mg), followed by 15 mg primaquine daily for 5 days. *Plasmodium falciparum* malaria cases were treated with 1,500 mg chloroquine (D0-600 mg; D1-600 mg; D2-300 mg), followed by a single dose of 45 mg primaquine. Children were given proportionally lower dosages. Primaquine was not given to pregnant women or infants. Personal consultations with patients or with their guardians were recorded by surveillance staff to elicit history of previous illness and movement to study the relapse pattern of *P. vivax* during the declining phase of malaria transmission (Sinha et al. 1989a). The sensitivity of *P. falciparum* to chloroquine was checked by the WHO 28-day extended *in vivo* tests (Sinha et al. 1989b).

Economic Evaluation

Economic evaluation of malaria in the industrial area for 1985, the year before commencement of bioenvironmental control, was performed with respect to expenditure incurred by the hospital management and loss of production to BHEL. The ex-

Table 2. Collection of indoor resting mosquitoes at 15-day intervals given as man-hour density estimates at BHEL complex from January 1987 to December 1995.

Species	No.	%
An. culicifacies	3,975	8.56
An. fluviatilis	231	0.49
An. stephensi	264	0.56
An. annularis	744	1.60
An. subpictus	12,048	25.97
An. splendidus	407	0.87
Other species	117	0.25
Total anophelines	17,786	38.34
Culex quinquefasciatus	28,603	61.65

penditure incurred by the hospital management on malaria has been calculated from the total budget of the hospital multiplied by the percentage of the budget that was spent on malaria.

An indirect measure of the monetary loss was calculated as follows (Ramaiah 1980):

$$\frac{(\text{annual turnover of BHEL}) \times H \times D}{(\text{no. of employees}) \times 365}.$$

H is the total number of BHEL employees who suffered from malaria in a year, and *D* is the estimated number of days the malaria patient remained absent from duty (assumed to be 5 days).

Statistical analysis: Statistical comparisons between the 2 groups were done with Student's *t*-test, while the correlation between 2 variables were calculated by the Carl Pearson method (Gupta 1987).

RESULTS AND DISCUSSION

Sixteen mosquito species from the genera *Anopheles* and *Culex* were recorded between January 1987 and December 1995. The prevalences of major species from BHEL area are given in Table 2. Of the total of 46,389 mosquitoes collected, 38.4% were anophelines and 61.6% were culicines. *Anopheles subpictus* was most abundant, followed by *An. culicifacies, An. stephensi, An. fluviatilis,* and *An. splendidus* among *Anopheles* species. The other anophelines were *An. vagus, An. maculatus, An. aconitus, An. nigerrimus, An. barbirostris, An. tessellatus, An. pulcherrimus, An. gigas,* and *An. lindesayi.* In addition to *Anopheles* and *Culex* spp., *Aedes aegypti* and *Aedes albopictus* were also found, particularly inside factory areas, but are not included in Table 2. Results of mosquito-breeding surveys inside factory areas are given in Table 3, which shows that most of the habitats were breeding *Culex* and *Aedes* mosquitoes. The intradomestic breeding was limited, and less than 1% of breeding habitats were found with larvae. The breeding in overhead tanks was almost negligible, and only 3 overhead tanks, which were unused or had a broken lid, were found to be positive for mosquito larvae. Therefore, *Aedes* breeding was mainly confined to peridomestic sites.

Source reduction and developmental work carried out at the BHEL site from July 1986, to December 1995, is given in Table 4. Fly ash was found to be most suitable to fill borrow pits, ditches, and other low-lying areas. A bulldozer and a tractor equipped with a bulldozer blade were used for a total of 2,248 h for filling and leveling of low-lying areas with fly ash and approximately 42,000 m^3 of fly ash was used for this work. All the drains were periodically cleaned, and uncemented drains were channelized regularly. Soak pits (247) were constructed in low-income residential areas for disposal of domestic wastewater, and stand pipes were constructed to supply piped water to the low-income colonies. Larvivorous fish were introduced to various habitats. *P. reticulata* was found to be very effective for controlling mosquito breeding in drains and underground tanks containing high concentrations of industrial pollutants. *Gambusia affinis* was found to be suitable for effluent ponds and ornamental tanks that contained clear or mildly polluted water. Periodic monitoring, cleaning of margins and removal of plant debris and algal growth is essential to ensure effectiveness of these fish as biological control agents (Dua and Sharma 1994a).

Table 3. Mosquito larvae breeding survey inside the BHEL factory area, Hardwar, from 1987 to 1989.

Habitats	No. surveyed	Total positive for immatures	No. positive for[1]			
			Anopheles	*Culex*	*Aedes*	Mixed
Iron containers and scrap metal	3,298	1,384	9	276	312	787
Used tires	688	380	—	2	148	230
Iron tanks	28	26	—	9	17	—
Underground tanks	151	58	14	11	21	12
Fire hydrants	24	12	3	—	—	9
Cooling towers	24	6	2	3	1	—
Drains	125	54	11	25	—	18
Miscellaneous	38	17	3	7	2	5
Total	4,376	1,937	42	333	501	1,061
%		44.3	2.2	17.2	25.9	54.7

[1] Species recorded were in the order: *Ae. albopictus, Ae. aegypti, Cx. quinquefasciatus, An. subpictus, An. stephensi, An. culicifacies.*

Table 4. Source reduction and developmental work carried out at the BHEL complex, Hardwar, from 1987 to 1989.

Type of work	Total
No. of positive breeding places eliminated	47,847
Earth work	
No. of ditches filled	6,533
No. of trucks/tractor trailers of fly ash/soil dumped in borrow pits/ditches	7,489
No. of h bulldozer/front dozer used for leveling work	2,248
No. of drains cleaned	11,343
Canalization (no.)	4,365
No. of soakage pits constructed	247
No. of overhead tanks covered	738
No. of cemented drains constructed (meters)	565
No. of stand posts constructed	28
No. of ventilation shafts covered with nylon mesh	1,050
No. of hatcheries established	8
Larvivorous fish stock (millions)	2
Development work	
No. of nurseries established	3
No. of trees planted	43,100
No. of playgrounds/parks	14
No. of improved wood stoves	502
Sanitation (no. of improvised latrines)	70

Underground tanks (95), sluice valve chambers (63), and sewage manholes (17) were treated with EPS beads. It may be noted that one application of EPS beads lasts for 2–3 yr; however, periodic checking and reapplication of EPS beads on uncovered surfaces is necessary to ensure effective control of mosquito breeding, as reported earlier (Dua et al. 1989). Bactoculicide and Spherix were effectively used to control mosquito breeding in different habitats specific to industries, e.g., iron scraps, where other methods, such as mechanical methods, application of EPS beads, and introduction of larvivorous fish, were not feasible. Bactoculicide was more effective for control of *Aedes,* while Spherix was found to be suitable for *Culex* and *Anopheles* mosquitoes. Moreover, one application of the bacterial larvicide may last for 4–6 weeks (Dua et al. 1993). Health camps (64) and group meetings (109) were organized to educate people about the bioenvironmental program. About 43,000 tree saplings were raised and were planted on reclaimed land.

Figures 1a–c show mean quarterly resting mosquitoes per man-hour collection of total mosquitoes, anophelines, and vectors in the experimental and control areas, respectively. The impact of intervention on vector anopheline densities was very pronounced. In particular, year-round vector densities in experimental and control villages were subjected to *t*-tests, and it was found that the vector densities in experimental and control villages were significantly different (Table 5). It was noted that the maximum density of *An. culicifacies* in the experimental areas was observed during the monsoon season from its breeding in the river Ranirao, which flows seasonally. A comparision of *An. culicifacies* density in riverine areas with that in other areas clearly supports the above observation (Fig. 2). Peak populations of *An. fluviatilis* occurred during postmonsoon months, and studies on the bionomics of this vector species revealed that it is a primarily zoophilic species with a zero sporozoite infection rate and hence is not considered to play a significant role in malaria transmission (Sharma et al. 1996). The density of *An. stephensi* was kept in check in the intervention area through mosquito-proofing of its breeding habitats.

Table 6 illustrates the malaria incidence at the BHEL site since 1986. The annual blood examination rate (ABER) dropped sharply between 1985 and 1995 while maintaining the same monitoring system, which implies that the amount of fever really declined. A follow-up of 2,176 cases recorded from 1988 to 1995 revealed that 685 (31.5%) cases were from surrounding areas outside of the intervention area, while 1,491 (68.5%) cases belonged to the BHEL site. Moreover, of the 1,491 BHEL cases, 299 (13.7%) were imported from other parts of the country. As no parallel data on malaria cases were recorded from control villages to evaluate the impact, slide positivity rate (SPR) and annual parasite index (API) for the years 1986 and 1995 were compared. The difference was found to be statistically significant ($P < 0.01$) in both the parameters substantiating the fact that as a result of intervention, malaria cases gradually decreased.

Plasmodium falciparum cases (113) were followed for the sensitivity of *P. falciparum* to chloroquine by *in vivo* testing. Results indicated that 29 (25.7%) were resistant of RI level and others were sensitive to chloroquine. All resistant cases responded to metakelfin. Studies on 2,555 *P. vivax* cases showed 251 (9.8%) cases of relapse after administration of radical treatment of primaquine. Second, third, and fourth relapses were also observed in 38 (1.48%), 6 (0.2%), and 4 (0.16%) cases, respectively, in spite of 5-day radical treatment each time.

The impact of intervention was measured in terms of vector density and malaria incidence. The vector density (total *An. culicifacies, An. fluviatilis,* and *An. stephensi*) was much lower in the intervention area than in the control area (Fig. 1c). Attempts were made to correlate man-hour density of *An. culicifacies* and API from 1987 to 1995, and a correlation coefficient of 0.6 was recorded. However, the correlation was found to be statistically insignificant, which may be due to imported cases and the coexistence of different *An. culicifacies* sibling species complexes. Similarly, there was a drastic reduction in malaria cases from 1986 base year to 1995. Moreover, the indigenous *P. falciparum* cases from the township were totally eliminated, and all the *P. falciparum* cases that occurred in the last 4 yr were considered to be imported. The reduction

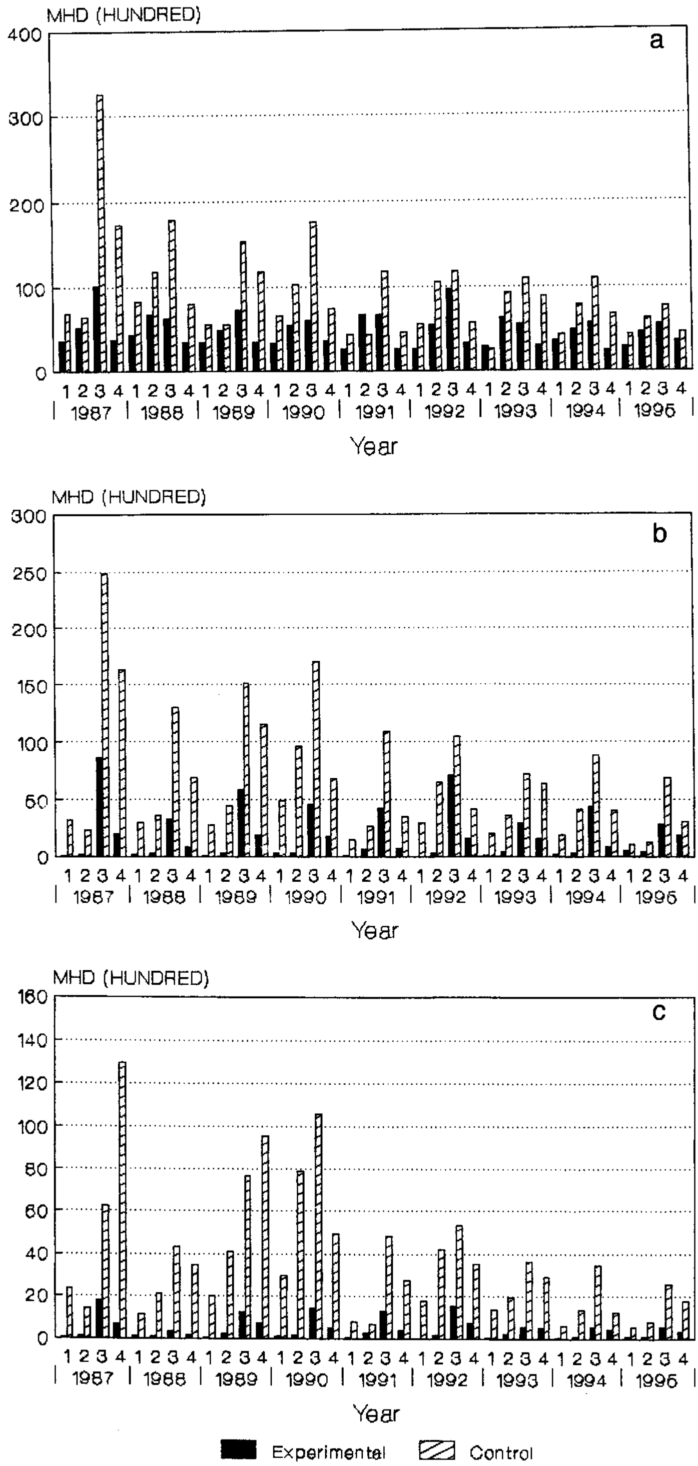

Fig. 1. Collection of resting (a) total mosquitoes, (b) total anophelines, and (c) total vectors presented as mean quarterly man-hour numbers in experimental and control areas, respectively, 1987 through 1995.

Table 5. Statistical analysis of *An. culicifacies* density in experimental and control areas.

Year	*t*	*P*
1987	1.96	0.0528
1988	2.23	0.04
1989	3.44	0.0024
1990	4.00	0.0006
1991	2.09	0.0486
1992	1.80	0.0858
1993	4.20	0.0004
1994	3.19	0.0043
1995	3.94	0.0007

in cases occurred in spite of heavy rainfall (Table 6). This implies that in spite of favorable climatic conditions for vector breeding, the malaria transmission was interrupted by the effective control operations.

The total expenditure on malaria at BHEL was about US $56,000, which included expenditure on patients as well as on malaria control measures. During 1985, there were 3,049 malaria cases recorded in BHEL hospital; 24% were BHEL employees, whereas the others were dependents. The annual turnover of BHEL Hardwar for 1985–86 was US $91 million (source: BHEL). Therefore, according to the Ramaiah formula, the loss in production during 1985 is estimated to be US $160,654. Therefore, the total 1985 cost of malaria (treatment, control, and production loss) is estimated to be US $116,654. The total loss during the project period (1986–95) would have been US $2,166,540. Expenditure incurred at the Malaria Research Centre (MRC) field station was US $316,440. It should be noted that the factory civil maintenance department was responsible for filling in borrow pits, ditches, and low-lying areas with fly ash, construction of community stand posts, and mosquito proofing of defective overhead tanks. Therefore, the expenditure incurred on these activities was not included in the total. Similarly, the bulldozer was provided free of charge by the Bengal Engineering Group of the Indian Army. A major portion of the expenditure at the MRC was incurred for the establishment of laboratories for basic research, which were not related to the field interventions at BHEL.

A study was carried out to compare the residual levels of DDT and HCH in whole blood between persons residing in BHEL Hardwar and in the adjoining area Bahadrabad where DDT and HCH were used for malaria control. Results showed that mean DDT and HCH levels in whole blood of persons from BHEL sites were 4.71 μg/l and 1.20 μg/l, whereas in Bahadrabad they were 38.13 μg/l and 24.3 μg/l, respectively. Thus, a significant difference was recorded in DDT and HCH whole blood levels between 2 areas of malaria control (Dua et al. 1996). This clearly suggests a major reduction in insecticide pollution as a result of shifting to the bioenvironmental control strategy for malaria control.

The strategy of residual spraying of insecticides is beset with many problems, such as insecticide resistance and concern about environmental pollution. In order to pursue the malaria problem on a long-term basis, the bioenvironmental control of malaria strategy was considered to be feasible, appropriate, and cost effective (Sharma and Sharma 1989). The implementation of a bioenvironmental control strategy at BHEL Hardwar was most successful. The impact of intervention measures was visible in the elimination of major mosquito breed-

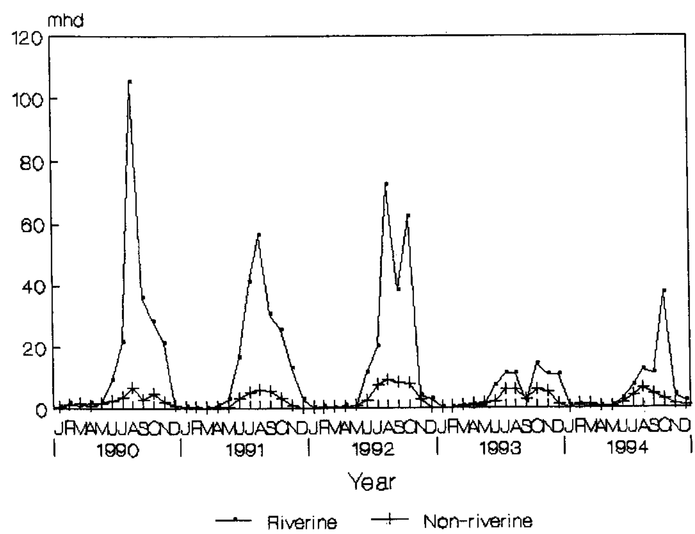

Fig. 2. A comparison of vector density (total of *An. culicifacies, An. stephensi,* and *An. fluviatilis*) in riverine and nonriverine areas at BHEL Hardwar, 1990 through 1994.

Table 6. Malaria incidence at the BHEL complex, Hardwar, 1985 through 1995.

Year	Total blood smears collected	Total positive	*P. vivax*	*P. falciparum*	Slide positivity rate (SPR)	Slide falciparum rate (SFR)	Annual blood examination rate (ABER)	Annual parasite index (API)	Annual rainfall (mm)
1985	20,273	3,049	2,620	429	15.0	2.12	45.05	67.7	1,150
1986	17,655	3,733	2,526	207	15.5	1.20	39.2	60.7	924
1987	14,767	593	569	24	4.0	0.20	32.8	13.2	637
1988	13,669	433	379	54	3.2	0.40	30.4	9.6	1,680
1989	8,516	425	414	11	5.0	0.10	12.2	6.0	1,450
1990	4,757	482	469	13	5.5	0.14	12.5	6.8	1,706
1991	7,153	337	327	10	4.7	0.14	10.2	4.8	1,100
1992	5,430	121	118	3	2.2	0.05	8.0	1.7	129.5
1993	3,341	93	86	7	2.8	0.20	4.8	1.3	139.9
1994	3,404	95	86	9	2.8	0.26	4.9	1.3	1,125
1995	4,346	190	180	10	4.37	0.23	5.79	2.53	1,470

ing sites over the campus. Effective case detection as well as prompt radical treatment ensured depletion of parasite load in the community, with the result that malaria transmission was greatly reduced.

One of the highlights of this project was the community involvement, including low-income residential areas and government and voluntary agencies, as well as the use of existing infrastructural facilities of BHEL. Community participation made the vector control program truly a people's movement toward self-help, awakening of health awareness, creation of better sanitation, and an improved environment. The study has shown that malaria control through an integrated approach is practical and sustainable in the long term. In addition, many collateral benefits have been achieved that cannot be quantified in terms of monetary gains.

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