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URBAN MOSQUITO CONTROL – A CASE STUDY

Emergence and resurgence of mosquito-borne diseases such as malaria, dengue, Japanese encephalitis and filariasis both in tropical and subtropical regions are well known. It is estimated that 500 million – one in every ten persons suffer from one or more tropical diseases and the global situation of lymphatic filariasis is reported as the 4th rank[1]. The geo-climatic conditions in India are conducive for the transmission of vector-borne diseases. The magnitude of the mosquito menace and prevalence of mosquito-borne diseases depend upon various factors such as developmental activities, human interference, climatic changes, availability of parasitic load in the community and socio-cultural practices[2].

In urban agglomeration, both man-made and other natural habitats form the mosquitogenic conditions conducive for the transmission of different vector-borne diseases[3]. *Culex quinquefasciatus*, an ubiquitous urban mosquito breeds mainly in drains, cesspits and cesspools containing domestic effluents and such habitats are extensive and diverse. This is due to insanitary conditions and environmental degradation. Lack of adequate housing, water supply, sanitation and solid waste management facilities, as well as knowledge, attitudes and practice (KAP) of the people are the major factors responsible for the proliferation of mosquitoes in the urban environment.

In India, there is no separate mosquito control programme as it is linked with sanitation and solid waste disposal, which is carried out by municipalities or *panchayats*. Most of the municipalities/corporations are unable to undertake mosquito control due to various reasons and seek the help of other organizations such as the Vector Control Research Centre (VCRC), Pondicherry which has developed Master Plans for the control of mosquitoes in Pondicherry[3], Bangalore[4] and Neyveli township[5]. While preparing the master plan simple, economic, ecologically sound, reliable, labour intensive and compatible methods both for the organization and the community were followed. In view of the severity of the mosquito problem, the technical guidance of VCRC was sought for the preparation of a master plan so as to undertake effective mosquito control measures in Cochin Corporation.

General Features of Cochin

The city of Cochin (Kochi) is situated between 9^0 58'N latitude and 46^0 14'E longitude, on the west coast of India in the Ernakulam district of Kerala, with a surface area of 94.88km^2. It occupies low lying area and the backwaters divide Cochin into two zones *viz.*, the east zone (Ernakulam) and west zone (Mattancherry). The total population of the Corporation is 5,64,489 (1991 Census) with a male to female ratio of 1:1. The literacy rate is reported to be total. The average population density in the Corporation area is 5,945/ km^2 with 1,00,914 houses. Cochin has a tropical humid climate with plentiful seasonal

rainfall. The temperature fluctuates within narrow limits in different months and the relative humidity is high throughout the year which reduces the rate of evaporation. The area receives the benefit of both south-west and north-east monsoons.

In most parts of Cochin, the underground water has been found to be contaminated owing to the high water table and the absence of a proper liquid waste disposal system. Therefore, water requirement for domestic purposes is met by the Kerala Water Supply Authority (KWA). Surface drains and canals are mostly used to drain sullage water into the backwaters. Due to lack of an underground sewerage disposal system for the entire city, septic tanks are used as the means for disposal of sewerage. In certain segments of the city, slabs have been used to cover the drains (box drains). As the drainage system is open in the rest of the areas, dumping of garbage in the drains is very common. Only a small area of 4 km^2 located in Ernakulam has an underground sewer disposal system.

Health Care Situation

Health care in Cochin city is rendered through a network of hospitals and dispensaries run by the government and private organizations, with a large contingent of private practitioners. There is no record of indigenous transmission of malaria. But there are cases of malaria, imported from elsewhere[6]. The occurrence of *Aedes aegypti* the vector of dengue has also been reported in these areas[7]. Many areas are perennially water logged and thereby prone to mosquitogenic conditions. Filariasis has been a major public health problem and this is evident from the fact that "Cochin leg" was the sobriquet of filariasis in this area even from 1709[8].

The magnitude of the mosquito menace of Cochin has drawn the attention of health planners as well as the common man. Despite the will and efforts of all concerned, the problem still continues unabated. All activities pertaining to health services for the people of Cochin are under the charge of the Corporation Health Officer (CHO), who is also responsible for mosquito control activities. There are two Assistant Health Officers (AHOs), one for the east zone (Ernakulam) and the other for the west zone (Mattancherry) who are also responsible for mosquito control works in their respective zones. Thus, the set up exists for mosquito control programme of the Corporation along with other health-hygiene related activities. Besides, National Filaria Control Unit (NFCU) under the control of a biologist, the Naval Base Authorities under the supervision of a Station Health Officer (SHO), the Southern Railway Authorities and the Port Authorities also carry out anti-mosquito measures independently in their respective areas.

Objectives of the Master Plan

The Cochin Corporation and the VCRC set up a joint action plan to prepare a Master Plan for the effective management of the mosquito problem with existing infrastructure and available resources, with the objectives to (i) identify and enumerate all potential mosquito breeding sources and quantify the relative role of different habitats in terms of daily mosquito emergence for prioritizing the areas for control operation; (ii) assess the magnitude of the mosquito menace problem through man biting density; (iii) evaluate the susceptibility status of the most abundant mosquito species against frequently used larvicides and adulticides to suggest the choice of insecticides; (iv) develop a mosquito control strategy by integrating different control methods suited to the local needs; and (v) impart training in control operations to all the staff engaged in this Programme and to design an IEC (Information, Education and Communiction) system for creating community awareness.

Study Observations

Mosquito breeding habitats

Mosquito breeding habitats identified were drains/ canals, septic tanks, cement tanks, pools/ponds, pit latrines, marshy lands, wells, overhead tanks, water meter chambers and miscellaneous household domestic containers. The potential breeding surface area in both west and east zones of Cochin is given in Table I. Emergence of mosquitoes from various habitats varied with the season and locality[9,10]. The contribution of drains except during the rainy seasons remained high, accounting for >90% of the total mosquito production from all other breeding sources. Profuse

Table I. Total surface area of different potential breeding sources (m^2)

Types of habitat	West zone	East zone	Total
Cement tanks	2,634	5,454	8,088
Cess pools/ponds	3,72,938	8,96,512	12,69,450
Canals	56,320	56,320	1,49,570
Lined drains	79,468	1,01,133	1,80,601
Septic tanks	67,617	96,566	1,64,183
Water meter chambers	2,992	2,201	5,193
Wells	1,991	4,055	6,046

breeding of mosquitoes in drains is due to stagnation of water at various points and also faulty gradient. Further, accumulation of silt and garbage invariably blocked the drains. There were 1.2 lakh septic tanks supporting prolific breeding of mosquitoes. Other habitats also contributed a considerable degree of mosquito production.

Problem of biting mosquitoes

The mosquito menace in Cochin was mainly due to the following night biting mosquitoes. *Cx. quinquefasciatus*, the vector of bancroftian filariasis(70.43%), *Cx.sitiens* (11.33%), *Armigeres subalbatus* (7.06%), Mansonioides, the vector of brugian filariasis (9.16%), Anophelines (0.26%) and other Culicines (0.94%). Day biting mosquitoes including the vectors of dengue and dengue haemorrhagic fever belonging to the genus *Aedes* (0.82%) caused considerable nuisance in parks and gardens and in posh colonies with green cover. The number of bites received by an individual in a year was 20 to 2352[9].

The larval susceptibility status of *Cx. quinquefasciatus* and *Cx. sitiens* against fenthion showed the LC 50 values 0.4132 mg /l for *Cx. quinquefasciatus* and 7.0×10^{-6} mg/l for *Cx. sitiens*[11,12]. Due to high literacy rate, most of the people are aware of the mosquito problem. Hence an intensive IEC campaign is warranted to involve various governmental and non governmental organizations, including the community as a whole in the control/prevention of mosquitogenic situations.

Approaches towards mosquito controls

The use of adulticides is not advisable owing to environmental hazards and prohibitive cost. Personal protection measures such as using mosquito nets or repellents are not a practical solution in view of the socio-economic background of the community and poor sustainability. The other approach is to eradicate immatures of mosquitoes or to make the habitats unsuitable for mosquito breeding through environmental modification/ manipulation. The latter may be considered as an environment friendly approach but cannot be applicable to all the habitats in all situations. Though such source reduction is a permanent solution for the prevention of mosquito breeding, it needs an engineering solution, which involves huge expenditure. Therefore, larvicidal operation considered to be an alternative measure of choice has received adequate attention in recent times[9]. The mosquito control activities of the Corporation includes spraying of mosquito breeding habitats with larvicide, fenthion 82.5%EC along with clearing blockades and cleaning of canals and drains. Fenthion has been used for the last three decades as a larvicide. Intersectoral coordination is an important component for the successful implementation of mosquito control programmes. However, there was an apparent gap between the engineering and health divisions with respect to mosquito control activities. For instance, faulty gradient in drains and canals is due to engineering defects and the early correction could have saved the recurring cost on insecticides. In septic tanks, insecticidal operation cannot be undertaken and hence appropriate remedial measures are suggested to correct the defects and implementation of measures to avoid mosquito breeding requires considerable exercise particularly in motivating and mobilizing the community, because the septic tanks are being maintained by the community.

Prevention of mosquitogenic conditions

An underground water pipe line system is the proper way of water disposal from residential areas. Since, a network of underground pipe line system is not available in the entire Corporation area, the open surface drainage system is the only alternate way of sullage water disposal. For the night soil disposal most people depended upon sanitary latrines connected to septic tanks. Pit latrines are uncommon. Due to the high water table and proximity to the backwaters and feeder canals, excreta are directly discharged into drainage water in some peripheral areas.

Recommendations

The results of studies by the VCRC showed that it is possible to contain the mosquito problem in the Cochin area with the existing infrastructure. However, it requires concerted efforts with a systematic approach. In this paper, the recommendations for effective implementation of the Programme are given based on the type of mosquito breeding habitats prevalent in the area.

Provision of a sewerage system will be an ideal solution to the problem. In this process, open drains will no longer exist and septic tanks can be removed totally. As a result not only will the expenditure on insecticides and spraying operations be reduced, but also the environmental pollution will be minimized. However, this can be considered as a long-term plan in a phased manner. The present recommendations are made for tackling the existing situation.

General recommendations

Environmental methods to control mosquitoes

Source reduction through environmental modifications has to be carried out in drains by correcting faulty gradients and removing the silt/ garbage. Spraying may also be avoided in such situations. Filling low lying areas with soil will prevent water accumulation. The silt and garbage removed from the drains can be used as source materials for such fillings in view of the non-availability of soil and the transportation cost. Unused/ disused wells can either be closed or sealed using concrete slabs. Polystyrene beads can be used as a physical barrier to prevent mosquito breeding in wells[13]. Through periodical removal of weeds, the ponds and canals may be made unsuitable for the breeding of *Mansonia* mosquitoes[14]. As the infestation of canals with weeds is influenced by various factors, such canals should be identified during the routine surveys and prioritized for such measures.

Monitoring the effectiveness of operations and reviewing the programme are of paramount importance to ensure the sustenance of an effective control programme. An action committee can be formed with a senior staff member /reputed senior citizen as the Chairman with local members to review the Programme from time to time and to overcome bottlenecks, if any.

Spraying operation

For successful and effective operations the target areas need to be prioritized, and adequate stock of insecticides should be ensured. The sprayers should be serviced as and when necessary for which spare parts need to be stocked. The staff should be allowed to concentrate on their allotted operational activities. To achieve good coverage in anti-larval operations deployment of spraymen in a particular area on a long-term basis and paying more attention to potential breeding habitats are necessary.

The larvicidal operations with chemical insecticides should be continued. Experience with biopesticides using *Bacillus sphaericus* in selected areas in the Cochin Corporation during 1991-93 indicated the development of resistance by *Cx. quinquefasciatus* and therefore the choice still remains with chemical insecticides such as the organophosphorus compound, fenthion[15].

Studies on the susceptibility status of *Cx. quinquefasciatus* and *Cx. sitiens* against fenthion have shown that both the immatures and adults are still susceptible[11]. This justifies technically the continuation of the use of fenthion as the larvicide of choice. However, monitoring of their susceptibility status is warranted from time to time. If there is development of resistance with the current larvicide, another most cost-effective insecticide can be chosen from the list of insecticides recommended (Table II). The susceptibility status of *Cx. quinquefasciatus* and *Cx. sitiens* towards adulticides such as DDT, BHC, bendiocarb, malathion and deltamethrin offers choices of adulticides in case of adulticidal operations, if any[12].

Spraying operations need to be continued at the concentration of 20ml of 82.5%EC of fenthion in ten liters of water to cover an area of 100 m^2. Further, this dosage needs to be ensured by checking samples collected at random. All the segments of open drains with water stagnation should be covered. Segments with free flow of water need not be sprayed. Effluent pools near the septic tanks should also be included under spray operations. Spraying should also be extended to canals that carry sullage water during the non-rainy months. Supervision needs to be enforced to ensure good coverage on spray operations by strictly adhering to the spray schedule.

Table II. Insecticides recommended for larvicidal operations

Insecticide	Chemical type	Dosage g(ai)/ha	Oral LD_{50} mg/kg(rat)
Fenitrothion	Organophosphorous	100-1000	503
Fenthion	-do-	22-112	330
Phenthoate	-do-	22-112	300
Temephos	-do-	56-112	8600
Chlorpyriphos	-do-	11-16	135
ML oil	–	19-47liter	negligible
Paris green(1%)	Inorganic	840-1000	22

Specific recommendations

Drains and canals

Lined drains are constructed on both sides of lane, streets and roads almost in all parts of the city. Domestic sullage water from the residential houses is discharged directly into these drains. In some areas, the sullage water is directly let into the nearby big backwater canal. In a few places, the drains are covered/ closed by cement slabs leaving man holes for cleaning and removing any blocks if clogged. Backwaters around the city are favoured as a terminal discharge points of the feeder drains. However, before being drained into the backwaters, the water stagnates in many

segments not only due to faulty gradients, but also due to damage or blockage with garbage. Wherever possible, faulty gradients should be rectified with the assistance of the engineering wing in a phased manner depending upon the availability of finances. Until such measures are undertaken, weekly larvicidal spraying needs to be carried out. This should be supplemented by silt/garbage removal. Availability of dustbins at reachable distance needs to be ensured to discourage people from throwing the garbage into the drain. Moreover, the community should be motivated to use the dustbins through appropriate IEC campaigns. Wide canals, with the breadth ranging from about 1-10 meters are common in many parts of the Corporation. Both the lined and unlined canals carry sullage water from the houses. While during the rainy season flooding facilitates the free flow of water, it becomes one of the sources of mosquito breeding during non rainy months. During this period larvicidal spraying operations need to be carried out selectively in this habitat also.

Septic tanks

Most of the 1.2 lakh septic tanks support mosquito breeding. Open vent pipes, open outlet pipes and damaged slabs make the septic tanks conducive for mosquito entry and breeding. The outlet pipes are either connected to open drains or open to form a pool, which support profuse breeding of mosquitoes. This is a technical problem as the liquid portion of the effluent needs to be let out, making such outlet pipes inevitable. When such pipes are diverted to the open ground, mosquitogenic pools are created. Regular spraying is required to monitor such situations. The outlet pipes also serve as entry and exit points for the mosquitoes. Attaching a water seal with a U tube device as shown in Fig.1a can serve as a permanent solution. To protect this device, a cover may be constructed as an extension structure. These water seals may also serve as the source for oviposition of mosquitoes. But, the resulting larvae will automatically be flushed out, either into the pool or drain where larvicidal spraying is a routine activity. Another simple, inexpensive method is to cover the opening of the outlet pipe with mosquito net (Fig.1b). As there are chances of this net getting damaged or removed, it needs to be replenished. The vent pipe-hood of septic tanks also serves as another entry point for the mosquitoes. These hoods should be covered with mosquito net. The hood for the vent pipes may be designed with small holes making it mosquito proof. Septic tanks with broken slabs pave the way for the entry of mosquitoes. Cracks and cervices resulting from improper covering also create mosquitogenic conditions. These defects can be rectified by replacing the damaged slabs with new, reasonably thick slabs or the cracks and cervices can be plastered with cement. The concerned households should be motivated to be responsible to carry out these repairs themselves.

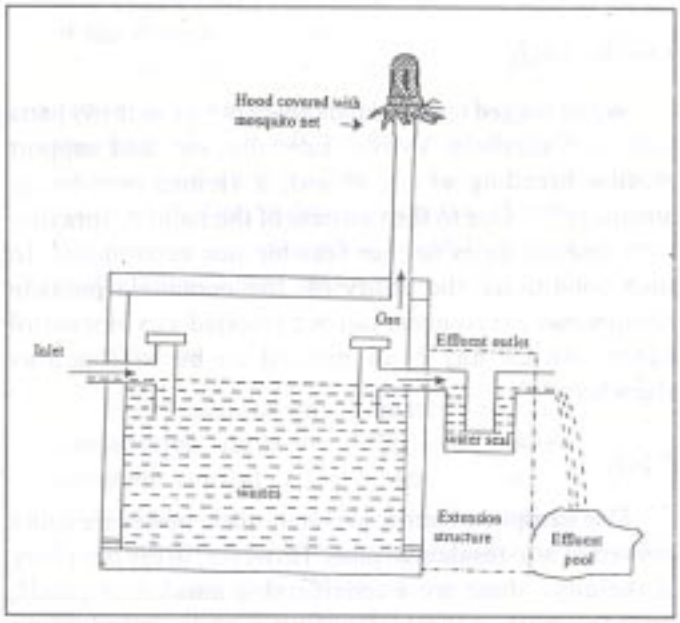

Fig.1a. Method of controlling mosquito breeding in septic tank

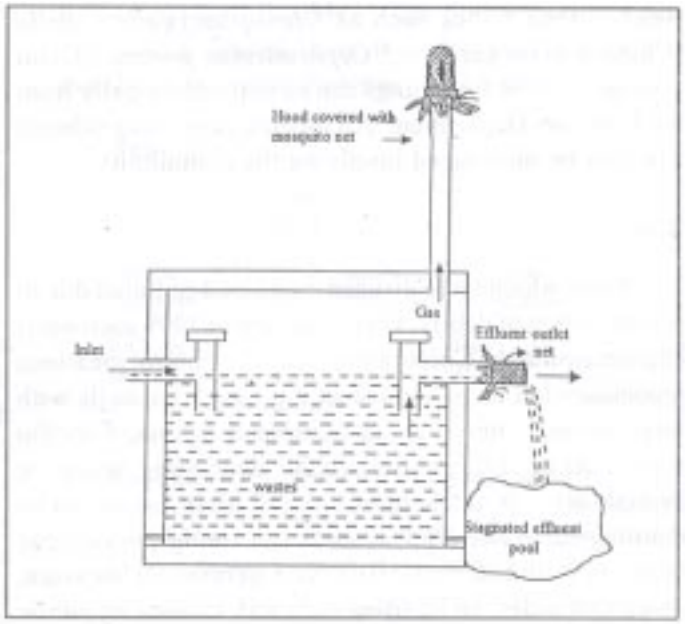

Fig.1b. Method of controlling mosquito breeding in septic tank

Cess pools

Water stagnation in vacant plots and barren lands also supports mosquito breeding particularly when these plots receive sullage water from the houses. Mosquito breeding can be controlled in such situations by (i) spraying larvicides; (ii) channeling–water can be drained out into the nearby drains/canals; and (iii) as a permanent measure the vacant plots should be filled to avoid water stagnation. The owners of the plots should be directed to fill these plots in public interest.

Marshy lands

Water logged marshy lands are common in many parts such as Vaduthala, Vytilla, Edapally, *etc.* and support profuse breeding of *Cx. sitiens*, a vicious man-biting mosquito[16,17]. Due to the vastness of the habitat, spraying with insecticide is neither feasible nor economical. In such conditions, the utility of the nematode parasite *Romanomermis iyengari* can be exploited as a biocontrol agent, which has been proved to be efficacious elsewhere[18,19].

Ponds

Due to rapid urbanization, man-made ponds are being converted into residential plots. However, in the periphery of the city, there are a considerable number of ponds, infested with aquatic floating weeds supporting Mansonioides mosquitoes, the vector of brugian filariasis. Mosquitoes in these ponds can be controlled by physical removal of weeds[14] and stocking the ponds with weedivorous fishes such as *Ctenopharygodon idella* (Chinese grass carp) and *Osphronemus goramy* (Giant gourami)[20]. The fingerlings can be collected locally from the Fisheries Department. An income generating scheme can also be introduced involving the community.

Wells

Wells which were disused remained polluted due to accumulation of debris. There were about 7499 such wells enumerated in the Corporation area. The control measures recommended include (i) stocking the clean wells with larvivorous fishes such as *Gambusia affinis*, *Poecilia reticulata* or *Aplocheilus blochii* depending upon the availability[21]. A hatchery of some of these fishes can be maintained to build up a stock.(ii) Using polystyrene beads in polluted wells. (iii) As a permanent measure, unwanted wells can be filled with soil. Closing of public wells can be carried out by the Corporation, whereas owners of private wells should be directed to do so. (iv) Wherever filling is not possible due to scarcity of soil and high cost of this exercise, the wells can be sealed with concrete slabs or wooden planks making them mosquito proof.

Miscellaneous mosquito breeding sources

Cement tanks, water meter chambers and overhead tanks are included in this category. These habitats are of minor importance[22]. Periodic emptying and cleaning of these habitats may keep them free from mosquito breeding. The Corporation should be empowered to take the necessary legal action as practiced by the Bombay Municipal Corporation against the erring householders who are found to promote mosquito breeding. Since Kerala receives rain during both the monsoons, the tree holes and peridomestic containers do support the breeding of the day biting mosquitoes. The local community can be motivated to remove or empty the receptacles around the premises. *Toxorhynchites*, a non-biting predatory mosquito can be used if necessary to control tree hole breeding mosquitoes.

Technologies for effective control

In box drains where insecticide cannot be sprayed, a drip applicator can be employed with the required quantity of insecticide at intervals of 10 meters[3].

Controlled release formulations with either chemical or biocide are known to release the active ingredient in a sustained manner at the required concentration to keep the habitat free from mosquito breeding . These formulations do not require any spray equipment and can be easily handled manually to prevent mosquito breeding for a prolonged period. In many stagnant polluted water habitats like cesspits, soakpits and septic tanks controlled release formulations can be used which are cost-effective and economic[23] . The pellets can be applied at the rate of 1 pellet /m^2 of the breeding habitat.

Estimated Operational Cost

The cost of mosquito control operations has been estimated in view of the strategies suggested and the infrastructure available with the Corporation for this purpose. The input costs are on account of the materials/ implements/equipments such as knapsack sprayers, scrappers, spades and bonds; insecticides such as Baytex (82.5% EC), ML oil and polystyrene beads; and personnel such as medical entomologists, junior health inspectors

(JHI) and field workers on spray operation, sanitation and evaluation. The expenditure quantified per annum is given in Table III. Some equipments like sprayers also had the maintenance costs–worked out 10% of the capital cost. The cost of materials such as scrappers, spades and bonds are considered as recurring cost as their useful life is a minimum of one year. The quantum of fenthion and ML oil required for treatment is estimated to be 1303 and 5650 liters respectively per year. The cost towards this will vary depending upon the market rate fluctuations as per the demand. Recruitment of two Medical Entomologists has been recommended as they will be assigned exclusively with mosquito control activities.

Table III. Estimated annual cost for mosquito control in Cochin Corporation area

Sl.No.	Cost of the items	Total cost (in Lakh)
1.	Materials/Implements	5.75
2.	Insecticides	38.86
3.	Personnel	346.44
	Grand Total	391.05

The actual cost on personnel in the form of salary is around Rs. 346.44 lakhs accounting for 88.59% of the total cost and thus the Programme is labour intensive. The salary of personnel also varies from year to year depending upon the changes in wages plus other allowances. The expenditure incurred by the engineering wing on personnel assigned with environmental sanitation and maintenance of drains and canals is not included. The total cost is estimated to be Rs.391.05 lakhs(Table III), which can be considered to be the minimum financial commitment required for effective mosquito control operations in the Corporation area. However, the actual cost on equipment, insecticides and salaries of personnel are subject to the marginal variations of 10 to 20% of the total estimated cost each year.

Proposed Organizational Structure

In view of the recommended strategy, restructuring of the present staff organization is suggested. For each circle, two JHIs need to be entrusted exclusively with mosquito control activities. While one JHI is necessary to look after the spray operations exclusively, the other has to implement environmental sanitary measures in addition to monitoring and evaluation. To carry out larvicidal operations, 158 field workers are essential and their allocation depends on the coverage. As many as 279 field workers are necessary to carry out environmental sanitation work such as cleaning and desilting the drains and deweeding the canals. As a feedback to the spraying and sanitation teams, the mosquito breeding sources need to be surveyed randomly with the help of two field workers in each health circle. They will be directly under the control of the respective JHI who is in-charge of environmental sanitation work. The Assistant Health Officer in the respective zone has to coordinate these activities and to solve the operational bottlenecks for the effective implementation of the Programme. The Health Officer of the Corporation has to be made the overall in-charge of the Programme. He must be entrusted to assess the progress of the operation and to convene periodical meetings to solve the problems that arise during the implementation of the Programme. Two Medical Entomologists can be recruited exclusively for mosquito control activities instead of Assistant Health Officers so that the services of the latter can be diverted for other health related activities.

Conclusions

Even though this study encompasses the entire Cochin Corporation, there are different agencies working on mosquito control in their respective territories such as the mosquito control unit of NFCP, Naval Base, Southern Railway and Port Authorities in Cochin. Coordination of all these agencies is desirable. A committee representing these agencies chaired by the Secretary, Corporation can periodically review the progress of related activities under these agencies. Without such a system, the real impact may not be realized. To make the Programme effective, it has been kept flexible so that the concerned authority can modify the details as and when required, in view of the changing mosquitogenic conditions.

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