3935

TRAVELLING WORKSHOP ON ENGINEERING ASPECTS OF VECTOR CONTROL AND BIOENVIRONMENTAL CONTROL OF VECTOR BORNE DISEASES

20 - 24 August, 1990

VENUE

Delhi, Hardwar, Haldwani

3935

NMEP/MRC TENTATIVE PROGRAMME FOR THE TRAVELLING WORKSHOP FOR SENIOR OFFICERS OF KARNATAKA GOVT.

Dates 20 to 24 August, 1990

Aug. 19, 1990: Arrival from Bangalore by Air. Halt in Delhi. Arrangements are being made in Guest Houses of the ICMR, NICD and Karnataka Bhawan etc.

Aug. 20, 1990: 9 A.M. to 12.30 P.M. Briefing Session- Venue: 20, Madhuvan, Delhi.

Bioenvironmental Control of malaria and related subjects (jointly by the MRC/NMEP).

Visit to the MRC laboratories

Video films

Field visit in Delhi.

Aug. 21, 1990: 10.00 A.M. - 12.30 P.M. General Discussion

12.30 A.M. - 1.00 P.M. Lunch, 20 Madhuban, Delhi-92.

1.30 A.M. : Departure to Hardwar by A/C bus.

6.00 P.M. : Arrival Hardwar, Tea etc.

7.00 P.M. : Bath in Ganges, visit to Har Ki Pauri

8.30 P.M. : Dinner

Halt in Hardwar. Arrangements are being made in guest house at BHEL/IDPL/Roorkee Univeristy etc.

Aug. 22, 1990: 8.00 A.M. - 12.00 P.M. field visit to see the malaria control work at the BHEL/IDPL and irrigation schemes etc.

12.00 P.M. - 1.00 P.M. Lunch

1.00 P.M. - Departure to Haldwani. Halt in Pant Nagar University and other guest houses.

8.00 P.M. - 9.00 P.M. - Dinner

Aug. 23, 1990: Departure at 7.00 P.M. to Haldwani.

Breakfast in Haldwani and field visit to see irrigation malaria and Banbassa head works. Halt in Haldwani.

Aug. 24, 1990: 7.00 A.M. Breakfast

8.00 A.M. - 10.00 A.M. Field visit & discussions.

11.00 A.M. - Departure to Delhi. Lunch would be arranged at a suitable place on way to Delhi.

In Delhi stay in the same guest house as on Aug. 19, 1990.

Aug. 25, 1990: Departure to Bangalore. Transport will be made available.

Notes:

1. A/C bus is being arranged. One car may also accompany the team.

2. Organisers would make arrangements for Tea/Coffee (2 times a day) and working lunch. For special meals request may be made in advance.

3. Please pay towards the guest house charges and other facilities such as tea etc. availed during the stay.

4. Breakfast and dinner would be arranged on sharing basis. Accounts would be settled on the last day.

5. Final settlement of per diem etc., would be made on 24 August. Some advance could be drawn.

6. Literature on various aspects of malaria control would be provided during the field visit.

The following officers would be responsible for arrangements:

Shri S.C. Sharma, Guest house arrangements, transport.

Dr. T. Adak - Tea/Lunch, Literature and field visits etc.

Dr. Aruna Srivastava - Committee Room etc.

Dr. V.K. Dua (Hardwar) and Dr. M. S. Malhotra (Haldwani) all arrangments related to stay, food, technical presentation and field visits.

List of participants would be sent separately as soon as it is received.

Workshop for Engineers, Architects, Town Planners and Health Administrators on Preventive and Corrective Aspects of Mosquitogenic Conditions Created as Incidental to Engineering Projects/Works

INTRODUCTION

It has been increasingly realised that malaria control based on insecticidal spray approach may not succeed due to various technical, financial and administrative limitations. The major ones being vector resistance to insecticides,necessitating the use of replacement insecticides at prohibitive cost, environmental pollution, harmful effects on beneficial fauna etc. The emergence of drug resistance in *P. falciparum* is aggravating the situation further.

This has resulted in high malaria transmission in urban, rural and industrial areas. As for example 60-70% of all malaria cases in Tamil Nadu are contributed by Madras city alone. In Visakhapatnam district (Andhra Pradesh) Visakhapatnam Steel Plant contributes 80% of all cases of the district and 35-40% of the state. Similarly, water resource development projects contribute to malariogenic potential in a big way. In Nainital district, Nanak Matha dam resulted in creation of water logged areas because initially it lacked seepage channels which had to be laid after the dam had broken down. In Hardwar (U.P.) the 2 industrial complexes viz., BHEL and IDPL had high incidence of malaria which was man made and simple engineering works corrected the situation. A similar situation exists in other industrial belts of the country such as in Gujarat and other endemic states.

At the same time case studies carried out in Delhi, Bombay, Madras, Goa, Calcutta and other towns, and rural areas throughout the country brought out that mosquitogenic potential was to a great extent related to faulty designing/execution and poor maintenance of engineering projects belonging to different sectors of economy. All urban areas are under stress due to influx from rural areas and population explosion, thus bursting at their seams. Various studies have shown that in India urban areas would expand to account for about 50% of the total population by the year 2000 AD. Local bodies are unable to cope up with matching resources and therefore adopt "ad hocism" in providing civic amenities, which are invariably inadequate. Under mounting pressure of population explosion the departments connected with housing, road building and water supply etc. draw their plans to meet the immediate needs but without ascertaining the long term adverse health impact. Such a haphazard growth results in increased incidence of disease and also makes it difficult to implement any remedial or corrective measures.

In order to develop an alternative strategy based on the integrated methods of mosquito control, role of engineers, architects, and town planners was considered crucial. The present series of workshops organized in the country is an effort to create an awareness among the professionals and seek engineering solutions to mosquitogenic problems generated by the execution of engineering projects/works.

OBJECTIVES OF THE WORKSHOP

- To impart elementary knowledge about the transmission of vector borne diseases, life history of mosquitoes and their habitats.
- To study the formation of mosquitogenic potential with varied types of engineering projects in different sectors of economy.
- Familiarisation with engineering design/execution of projects to prevent mosquitogenic potential at the design stage and thereafter.
- Field visits to study good and bad engineering works in regard to mosquitogenic potential and recommend corrective measures.

1. DELHI

1.1 Endemicity to vector borne Diseases

Delhi is endemic for malaria recording over twenty five thousand cases annually. In years of heavy rains and floods these figures far exceed (over 4 lakh cases in 1978). Malaria is contributed by two Anopheline species viz., *Anopheles culicifacies* and *A. stephensi.* While the former is a monsoon associated species & breeds in fresh water collections on ground, the latter is a container habitat species & breeds in wells and in all types of domestic storage containers. Delhi is also endemic for dengue fever, a viral infection transmitted by *Aedes aegypti* which again breeds in domestic and peridomestic situations. Besides malaria & dengue, Delhi is plagued with very heavy population of pest mosquito, the *Culex quinquefasciatus*. The species breeds in polluted water & have two peaks of population first during March-April & other in September-October.

1.2 Contributory Factors

Major sources contributing mosquitogenic potential for various vector species are as follows:

(a) *A. culicifacies* (Vector of Malaria)

(i) Embankments of river Jumna with faulty slope towards embankment & stagnating rain/flood water.

(ii) Large scale excavations in Rajghat complex connected with National memorials and Indra Prastha (I.P.) stadium.

(iii) Lack of outfall in the drainage system of Zoological Gardens.

(iv) Draining of I.P. thermal power water affluent into Khaddar land.

(v) Excessive mining in and around Jawahar Lal Nehru Universty Campus.

(vi) Non-dressing of borrowpits and brick kiln fields.

(b) *A. stephensi* (Vector of malaria)

(i) Water supply carriage and its regulatory mechanism i.e. sluice valve chambers.

(ii) Overhead tanks, wells, storage tanks, ornamental tanks, swimming pools, desert coolers etc.

(c) *Aedes aegypti* (Vector of dengue fever)

(i) Domestic/peri-domestic water storages

(ii) Tyre dumps

(iii) PWD junk yards

(iv) Water coolers/Air conditioners

(d) *Culex quinquefasciatus*

(i) Twelve sullage/sewage drains discharging into 'Khaddar land' of river jumna and its utilization for wet cultivation.

(ii) Drains of housing complexes without outfall for sullage/sewage disposal.

(iii) Laying of drains without embedded cunettes particularly under administrative control of flood control department.

2. GOA

2.1 Endemicity to vector borne diseases

All these years malaria has been a rural disease in Goa. With the extension of NMEP unit in 1963, the disease had been very much under control. Incidence of malaria between 1963 to 1974 ranged between 6- 175 cases per annum. However during 1975/76 the incidence touched record figure of 2012 cases as elsewhere in the country & the cases came down to mere 80 in 1985.

During 1986, malaria established a strong hold in urban areas. The first city to be affected was Panaji. Malaria figures showed a steep rise in 1986 when 352 cases were recorded in a population of 50,000. The incidence rose to 4416 cases in 1987 & 4302 (upto Aug.)in 1988 thus accounting for epidemic situation in the capital.

Besides malaria Goa is also endemic for filariasis and Japanese encephalitis.

2.2 Contributory Factors

(a) *A. stephensi* (Vector of malaria)

(i) Faulty water carriage system. Impoundment of water in sluice valve chambers at Ultino.

(ii) Stagnation of water in regulatory chambers on each distribution line from leakages.

(iii) Non-mosquito proof overhead tanks, ground storage tanks and water storage practices in areas with limited hours or water supply limited hours.

(iv) Ornamental tanks/swimming pools with faulty design.

(v) Water storage practices at construction sites.

(b) *Culex quinquefasciatus* (Vector of filariasis)

(i) Drains with faulty gradients

(ii) Non mosquito proof septic tanks

3. BOMBAY

3.1 Endemicity to vector borne diseases

Bombay is the only city in the country which is strictly following the policies laid down during British days for malaria control. These policies basically revolve around engineering solutions and are implemented through a series of stringent bye-laws. Consequently malaria incidence in Bombay Metropolis never exceeds 2,000 cases per year. In recent years it was only during Indo-Pakistan war 1965 when the cases crossed these figures, as most of the sealed wells were opened to meet the war exigencies. The incidence was brought down by 1971, when all the wells were re-sealed.

Other mosquito borne infection which exists in Bombay is filariasis, however the incidence is more in sub-urban Bombay.

3.2 Contributory Factors

(a) *A. stephensi*

A. stephensi problem has been adequately contained by stringent legislative measures as follows:

(i) *Wells* : Existing wells have been covered with RCC slabs and hermetically sealed.

(ii) *Cisterns*: A standard mosquito proof design as formulated by Municipal Corporation of Greater Bombay nly permitted. No objection certificate from local malaria officer is a pre-requisite for granting water connection.

(iii) *Fountains, garden tanks, tubs*:

(iv) Not permitting fountains which holdwater when idle.

(v) Garden tanks without bottom flush and not connected to municipal drain are not permitted.

(vi) *Cellars*: To be filled upto percolating level of sub-soil water.

(vii) *Constructicn sites*: Buildingdeposit bye-laws enforced to eliminate breeding potential at construction sites.

(b) *Culex quinquefasciatus*

High populations are encountered in different areas as follows.

A. Unsewered areas

(i) *Septic tanks and aqua privies:* Major source for breeding of mosquitoes.

(ii) *Surface drains:* Breeding facilitated by lack of gradient, obstruction of flow by crossing of service lines, Improperly laid cross culverts, garbage accumulation, silting and rodent excavations.

(iii) *Covered surface drains:* Covering of surface drains by cement slabs renders the drains inaccessible for anyanti- larval activities.

(iv) *Natural water courses:* Earlier natural water courses now turned sullage carrying drains breed profusely because of emergent vegetation, water hyacinth and growth of grasses.

B. Sewered Areas:-

(i) *Surcharged condition of sewage*: Surcharged conditions of sewer often leads to stagnation and conse quent mosquito breeding.

(ii) Discharge of surcharged sewers into an open storm water drain which encourages breeding.

(iii) *Wet cultivation:* Cultivation with sewage water accounts for prolific breeding.

C. Kurla Mahim Creek - Pest mosquito problem

Kurla Mahim Creek over a period of time got narrowed down at its mouth by construction of approaches for rail and road bridges, cause ways, water lines which resulted in lowering the flushing effect of tidal waves and thus the salinity upstream. Mangrove in the upper part of the creek build up high density of *Culex gelidus* a pest mosquito which breeds in waters with very low salinity.

4. MADRAS

4.1 Endemicity to vector borne diseases

In Tamil Nadu, urban towns together contribute about 70 per cent of total cases reported from the whole state. Madras city alone contributes major share. Over the last 5 years, on an average Madras city accounted for 75 to 80 per cent of fever cases reported from urban areas.

Besides malaria, filariasis is also endemic in Madras city. Annual surveys carried out during the last three years have shown microfilaria rate ranging from 1.2% to 1.7% while the disease rate varied from 0.2% to 0.3%.

4.2 Contributory factors

(a) *A. stephensi*

(i) Chronic scarcity of water has necessitated dependence on wells as principle source of water supply which becomes the primary source of breeding of *A. stephensi.*

(ii) Existence of non-mosquito proof overhead tanks and ground storage tanks.

(iii) Increased tendency of domestic storage necessitated by intermittant water supply.

(iv) Storage practices around construction sites for curing purposes.

(v) Construction of OHTs in housing colonies without piped water supply which in turn retain rain water due to open design.

(vi) Lack of access to OHTs in housing complexes belonging to Housing Board thus making remedial actions difficult.

(b) Culex quinquefasciatus

(i) *Adayar River:* Adayar river, a sullage carrying river on account of topographical constraints is a decaying river at its entrance point into the sea. Retarded flow encou rages growth of weeds/other vegetation which permits prolific breeding of culicine mosquitoes. However this phenomenon got neutralized by flushing action of tidal waves upto 4 to 6 Kms. upstream and the resultant increased salinity kept the river free of breeding. But due to strong wind action developed under influence of southwest monsoon and northeast monsoon, the river got blocked with "Sand Bar" and prevented the flushing action of tidal waves. This phenomenon leads to build up of very high population of Culex mosquitoes.

(ii) Abandoned pits dug along coastal areas by inhabitants to retrieve drinking water.

(iii) Lack of gradient of sullage carrying drains of housing board.

(iv) Accumulation of sullage in borrow pits/depressions for lack of outfall.

5. RECOMMENDATIONS & REMEDIAL ACTIONS

5.1 Administrative (Action by Government of India)

5.1.1 Statutory Body for Health Clearance : Each town should have "Statutory Body" for planning and control of Urbanisation, analogous to "Art Commission" in Delhi. Scope of this body should be enlarged to include health components which would examine adverse health impacts and associated mosquitogenic potential and would suggest essential anti- malaria works.

5.1.2 A Committee may be constituted comprising of experts from NMEP, MRC, Ministry of Education, Universities and IITs to study and formulate course curriculum on mosquito borne disease control (both preventive and corrective) using engineering methods for various levels of engineering courses.

5.1.3 'Bureau of Indian Standards' can play a leading role in bringing out a "code of practices" on specifications of essential anti malaria works of Engineering Projects.

5.2 Technical (Remedial solutions to be adopted)

As the breeding habitats of vectors are species specific, hence the recommendations for remedial actions are covered species wise. These will be applicable to all urban areas.

5.2.1 *A. stephensi* and *Aedes aegypti* (Vectors of urban malaria and dengue fever)

(a) *Water supply system* (Carriage, storage and distribution)

Problem : Water collections due to leakages in masonary chambers and surface boxes for fire hydrants, water meter, stop cock, sluice valves, other valves and hydrants.

Remedial Actions : Adequate preventive maintenance measures and continuous monitoring should be initiated and strictly observed to prevent leakages. Masonary chambers & surface boxes of sluice valves/regulators and the like should be provided with "soakpits" below the base. Wherever site conditions permit drain pipes may be installed to drain away the leakage water directly.

(b) *Domestic Storage installations*

Problem : (Overhead tanks, Ground storage tanks)

(i) Non-mosquito proof manhole covers

(ii) Manhole covers of removable nature

(iii) Improper access for surveillance

Remedial Action : The practice followed in greater Bombay Municipal corporation should be extended to all urban towns. The design provides for sturdy manholes cover with lockup arrangement and provision of fixed ladder for access.

(c) *Wells*

Problem : Open drinking water wells and disused wells form the primary sources of breeding mosquitoes.

Remedial Actions: (i) Drinking water wells should be hermetically sealed. For extraction of water, suction pump should be provided over the well top or installation of pumping set be provided by the side of the well, (ii) All Inlets or draw down pipes should be properly sealed. If ventilation pipe or shaft is provided it should be capped with mesh screen with holes not exceeding 1.5 mm as mosquito proof terminal.

(d) *Construction design of building sunshades, portico and Roof gutters*

Problem : The rain water trapped in articles stored at construction sites, stagnation in the top of receptacle shaped sun shades, porticos, clogged roof gutters provide ideal breeding place for mosquitoes.

Remedial Actions: (i) Education of all concerned (ii) Passage of adequate rules and amendment in specifications andbye-laws governing the design and construction techniques.

(e) *Cellars and Basements, Lift pits, Storage for curing*

Problem : Stagnation of water for curing encourage breeding of mosquitoes.

Remedial Actions: (i) Provision should be made of adequate spouts in depressions to drain the water in 6 days cycle and if again needed for curing fresh water be filled in (ii) Provision should be made of pumping arrangements in lifts, pits, cellars and basements where natural drainage is not possible. The water should be pumped in 6 days cycle. (iii) Proper maintenance system must be evolved to follow the above procedures.

(f) *Fountains, ornamental tanks and swimming pools*

Problem : Stagnation of water while lying idle provides ideal breeding sources for mosquito breeding.

Remedial Action: Provision should be made for bottom flush outlet and the same be connected to the municipal drain.

5.2.2 *A. culicifacies* (Vector of malaria)

(a) *Embankment of River Jumna (Delhi)*

Problem: Slope gradient towards embankment encourage stagnation of rain water/receding floods.

Remedial Actions: (i) Lead for earth required for bund (embankment) should be taken from a distance so that there remains adequate slope towards the water channel (ii) existing faulty embankments should be realigned using bulldozer to maintain adequate slope towards water channels.

(b) *Outfall of fresh water into khadder land of Jumna (Delhi)*

Problem: Storm water from I.G. Stadium and Rajghat complex is pumped into khadder land & spreads out before joining the water channel and forms ideal breeding site for malaria vectors. The Installation of chamber and draining of water through open jointed pipes into river channel as it would eliminate the problem of water stagnation on permanent basis.

Remedial Action: (i) Storm water from the outfall pipe should be trapped into a chamber and then drained through open jointed pipes into the water channel. The sandy bed will prevent leakage from open joints. Exercise to be carried out after monsoon & pipes removed before monsoon period again to be relaid after monsoon.

(c) *Thermal Power Station (Delhi)*

Problem : Water at outfall point from fly ash tanks spread over Khadder land & generate mosquitogenic potential.

Remedial Actions: (i) Water may be drained through removable open jointed drains corresponding to monsoon & lean period flow of river channels, and (ii) Slurry ash tanks may be deepened and provided with filter and suction pump at the bottom & water recycled into the plant, a technology as adopted by BHEL unit at Hardwar, Uttar Pradesh.

(d) *Zoological Park (Delhi)*

Problem : Water for zoological park is pumped into borrow pits of rail track between New Delhi-Nizamuddin Rly. Station.

Remedial Action : Water from Zoological Park should be provided with an outfall connected to river Jumna or the water can be utilized for horticultural purposes in the adjacent sanitary filling areas.

(e) *Excavations (Borrow pits, quarry pits etc)*

Problem : Stagnant water generates high breeding potential for malaria mosquitoes.

Remedial Action : An appropriate clause should be incorporated in the agreement making the contractors responsible for dressing the excavations so that there is no stagnation and the borrow pits find gradient up to the nearest natural drainage system.

5.2.3 *Culex quinquefasciatus* - (Vector of filariasis)

(a) *Plugging of River Adayar by Sand bars (Madras)*

Problem : Due to lack of gradient river gets plugged by sand bar under wind action and generates high mosquitogenic potential.

Remedial Action: (i) Dredging should be carried out periodically at the mouth of the river to maintain the flow as well as entry of tidal water upstream. (ii) Large sullage carrying drains should be suitably designed with proper gradient of adequate capacity to meet the discharge requirements. To meet the lean period flow, the bed of drain should have embedded with cunette of adequate capacity. The bed of drain should be provided with a slope towards cunette, to prevent any stagnation at the uppe deck (iii) Partially covered drains with cement slabs should be avoided as far as possible from the maintenance point of view, as it is easier to maintain regular flow in the drains if it is open in comparison to partially covered drains, and (iv) Deweeding/desilting of drains should be undertaken regularly throughout the year to maintain adequate flow instead of undertaking such operations only once in a year - I.e. during monsoon.

6. HARDWAR

6.1 Industrial Malaria

Setting up of heavy industries are always associated with large scale excavations connected with levelling of land for erection of tactory sheds, network of roads for movement of machinary and finally movement of migrant labour. Water collections in the excavations, setting up of labour camps without appropriate means of water supply and their disposal results in high build up of vector populations and local & focal outbreaks of malaria. In Hardwar setting up of a Unit of Bharat Heavy Electrical Limited resulted in steep rise in malaria cases under similar circumstances. MRC Hardwar unit developed alternate technology based upon environmental methods of control to deal with the situation which is briefly summarized below.

6.2 Problems in Bharat Heavy Electricals

(i) Heavy excavations in connection with levelling of sites.

(ii) Excavations dug by inhabitants of unauthorised labour colonies.

(iii) Lack of drainage at water stand posts.

(iv) Lack of gradient of storm water drain.

(v) Disposal of flyash and water affluent of Thermal Power Station.

6.3 Modernised Parallel Upper Ganga Canal

In the excavation areas (at present abandoned) there exists heavy water logging carrying high mosquitogenic potential.

6.4 Ganga Project on Prevention of Pollution

Sewage affluent from Rishikesh generated high potential for breeding of Culex mosquitoes and proved a great curse for local population.

6.5 IDPL Factory

Sewage affluent from IDPL factory generated similar problem in Pashulok area.

6.6 Solutions Developed by MRC, Hardwar

6.6.1 *Bharat Heavy Electrical Premises*

(i) *Excavations :*

Excavations of all magnitude ranging from ponds of labour colony to large depressions are being filled with fly ash produced by Thermal Power Unit at BHEL.

(ii) *Water stand Post :*

All the water stand posts were re-aligned to permit outfall of waste water to the nearest natural drains.

(iii) *Storms water Drains*

Storm water drains and disused cement tanks were stocked with larvivorous Gambusia fish.

(iv) *Sluice valve chambers*

All such chambers retaining water resulting from leakage were stocked with Polystyrene beads (EPS).

(v) *Thermal Power flyash/water affluent*

Disposal of water affluent problem has been solved by adopting a "New technique" which permits laying down of a suction pump at the bottom of ash settlement bank & the water is recycled into the plant without causing any mosquitogenic potential in contrast to Delhi where water affluent is recycled into the river & creates a high mosquitogenic potential. Fly ash is being used as a filling agent within the BHEL area, which otherwise accounted for Rs. one million/per annum to the Plant for its disposal.

6.6.2 *Construction of modernised parallel upper ganga canal*

Construction of Parallel Upper Ganga canal designed to carry 370 cusec of water is a long term project of the Irrigation Dept. of Govt. of U.P. Initial stages of excavation of canal has resulted in large scale borrow pits and water logging which permit heavy breeding of malarial mosquitoes. The following short term and long term measures have been adopted.

Short term : The large bodies of water are being stocked with *Gambusia affinis* to check breeding during the construction phase of the canal.

Long Term : In long term, canal is unlikely to produce mosquitogenic potential as it is being constructed adopting a new technology for lining of slopes and bed with LDP (Low density polythene) film where water table is lower than bed level. Although primary aim is to prevent seepage losses but incidently it is this seepage water which not only results in water logging of the area and renders the soil unsuitable for cultivation, but also creates marshes suitable for breeding of Anopheline mosquitoes and thus making the area highly malarious.

6.6.3 *Ganga projects on prevention of pollution*

Before the launching of Ganga Action Plan the entire sewage from Rishikesh (about 6 million litre/day) used to produce millions of mosquitoes besides polluting Ganga river. Action Plan envisages pumping of whole sewage to "Muni Ki Rati" and Maya Kund, Oxidation ponds. After retaining the water for 15-21 days depending upon BOD loading the water is recycled for irrigation purposes at Pashulok farm and by private cultivators at Lakadghat village.

6.6.4 *IDPL Factory*

IDPL factory industrial waste water was collected in a pond and nearly low lying areas in Pashulok area and provided high potential for breeding of *Culex* mosquitoes. MRC unit diverted this water to main drain downstream & constructed a new drain to carry water for irrigation purposes thus eliminating this great health hazard.

7. NAINITAL

7.1 Rural Malaria - Haldwani/Nanak Matha/Banbasa.Tanak Pur Hydro Electric Project

Being located in the foothills and Terai region of distt. Nainital, the area had gained the notoriety of "Death Trap" on account of presence of hyper endemic type of malaria. With the launching of NMEP, malaria was controlled to a very great extent and land reclaimed. The area is now considered to be the granary of the country.

However, various developmental activities undertaken in irrigation sector brought in a new potential for breeding of malaria mosquitoes and the area is since then experiencing pers stance of transmission.

7.2 Field Visits to Problem Areas

(i) Visit to NMEP control unit Rudrapur : The unit follows residual spraying with BHC on API basis, surveillance & treatment through MPW scheme.

(ii) Haldwani field station of MRC : The unit looks after a set of 180 villages by an integrated disease vector control (IDVC) approach. Demonstrations arranged at Gandhapur village included stocking of cattle drinking pits/ponds with *Gambusia affinis,* filling of excavations holding water, and application of EPS beads around biogas plants.

(iii) Nanak Matha Dam

(iv) Sarda Canal Head works at Banbasa

(v) Hydro-electric Project, Tanakpur

7.2.1 *Problems at Nanak Matha Dam*

(i) Water logging resulting from erosion, generated by flushing action forms pockets of stagnant water for mosquito breeding.

(ii) Perennial seepage of water from dam & also the seepage channels resulting in creation of marshes for mosquito breeding of *A. culicifacies.*

(iii) Pockets of stagnant pools at shore line due to falling level of water reservoir.

7.2.2 *Problems at Sarda Canal Head Works*

Built in 1920-29 and mainly used for irrigation. It was previously a malaria endemic zone, but well managed with environmental methods of control by construction of "anti-malaria drains" which passed through ground channels below the main canal back to the river. Severity of the disease is reflected by 8,000 deaths due to malaria reported during the entire period of the project.

Problems in recent times include (i) lack of maintenance of drainage channels, (ii) lack of funds and (iii) lack of intersectoral coordination.

7.2.3 *Solutions -Nanak Sagar Dam*

The major problems were in the design process:

(i) Pitching of rubble opposite flushing gate needs corrective measures in design to prevent soil erosion and subsequent formation of ditch.

(ii) Seepage channel needs proper drainage up to the nearest natural drain with suitable gradient without causing formation of ponds in its route.

(iii) Shoreline area should be so aligned that it should not form stagnant pools with the fall of reservoir level.

7.2.4 *Solutions - Sarda Canal Head Works*

(i) The area should be properly surveyed with regard to the level of sub-soil water at various points and a general plan for drainage should be prepared and existing drainage system should be suitably augmented.

(ii) Existing open drainage system should be replaced by modern technology of sub-surface drains as developed by Central Soil and Salinity Research Institute, Karnal (Haryana). Sub-surface drainage inter alia includes perforated corrugated PVC drainage pipes and synthetic drainage filters. These drains are provided with inspection chambers. Sub-surface drains, besides being cost effective with long life dispense with requirement of routine maintenance of obstruction caused by falling leaves and weed growth in open drains which encourages mosquito breeding.

8. HYDRO ELECTRIC PROJECT - TANAKPUR

Hydro-electric project under construction by National hydro- electric Corporation is situated 25 km upstream of Banbasa. The design includes construction of barrage with 22 bays with afflux Bund on both banks. The design includes laying of open surface drains to deal with seepage water both at the afflux bund and along power line canal.

Since the open drain system is fraught with danger of mosquito breeding in the event of poor maintenance, project authorities were impressed upon to use modern technology of laying sub-surfacedrains instead of open drains based on new technology. Equal emphasis was laid on proper disposal of seepage water into natural drainage system without creating stagnation en route.

9. RECOMMENDATIONS

9.1 Administrative (action by the GOI)

9.1.1 A high level meeting may be convened to examine the adverse health impact of developmental projects in all sectors of economy in respect of receptivity and vulnerability to vector borne diseases.

9.1.2 A committee may be constituted comprising of experts from NMEP, MRC, Ministry of Education, Universities and IITs to study and formulate course curriculum on mosquito borne disease control (both preventive and corrective) using engineering methods for various levels of engineering courses.

9.1.3 Considering the serious health hazards associated with engineering projects, it is essential that all projects are scrutinized from health point of view and approved by the competent health authorities nominated by the GOI. This authority should be involved at all stages from planning to maintenance.

9.1.4 Bureau of Indian Standards can play a leading role in bringing out "a code of practice" on specifications of Essential Anti- Malaria works of Engineering Projects.

9.2 Technical (to be adopted)

9.2.1 To create general awareness, workshops on malaria control for engineers should be conducted for Senior Engineers in each State/U.T.

9.2.2 Engineers appreciated the fact that much of the problems could have been prevented but for lack of awareness among Engineers and Architects. To meet this challenge, it was recommended that a "Manual on Malaria Control for Engineers" should be prepared for distribution to be implemented by all engineering deptts throughout the country. Similarly a chapter on "malaria control" should be introduced in all degree and diploma courses.

9.2.3 Realising that rural malaria is largely contributed by untidy irrigation practices, resulting in formation of stagnant pools down stream of barrages, earthen dams, canal/river embankments, waterlogging due to seepages, and inadequate drainage etc.it is recommended that emphasis should be laid on tidy irrigation i.e., use of conduct or lined canals with LDP films, design of canal gradients and cross sections to ensure atleast 60 cm/sec velocities, use of sub-soil seepage canals to prevent seepages from dam/ water logged areas to prevent breeding of *A. culicifacies* in fresh waters.

9.2.4 It is recommended that to prevent breeding of *A. stephensi* and *Aedes aegypti* the container habitat species, domestic storage containers should be rendered mosquito proof. These should include overhead tanks, ground level storage tanks, and wells. This should be ensured by stringent bye-laws to ensure construction of specified design and to maintain mosquito proof status thereafter.

9.2.5 For proper drainage of sullage water in urban areas, drains should be suitably designed with proper gradient of adequate capacity to meet the discharge requirements. To meet the lean period flow the bed of the drain should have embedded cunette of adequate capacity. The bed of drain should be provided with a slope towards cunette, to prevent any stagnation of water at the upper deck.

9.2.6 Covering of drains having regular flow of sullage should be avoided as far as possible from the maintenance point of view, as it is easier to maintain regular flow in the drains if it is open in comparison to the covered drains.

9.2.7 Desilting/deweeding of drains should be undertaken regularly throughout the year to maintain adequate flow instead of undertaking such operations only once in a year i.e. during pre-monsoon period.

9.2.8 It was observed that the technique of the disposal of flyash and water affluent from thermal power plant at Hardwar was a correct method and the same should be adopted at Delhi. In the former case water was recycled into the plant and did not create any mosquitogenic conditions. Fly ash could be utilized for filling depressions/borrow pits/excavations which otherwise can not be filled by sanitary filling.

9.2.9 It was observed that distinction must be made in the drainage of seepage water from earthen dams (Nanak Matha) and sub-soil water from water logged areas (Sarda Canal). It was recommended that while in the former case drainage channels should have proper gradient free of weed growth & connected to the nearest natural drain. In waterlogged area, recently developed technology based on sub-surface drains using perforated PVC pipes as developed by Central Soil and Salinity Research Institute, Karnal should be adopted as besides being cost- effective it does not create any mosquitogenic potential being closed in comparison to open drains.

9.2.10 Authorities at Tanakpur Hydro-electric Project were impressed upon to follow the new technology of sub-surface seepage drainage in their project area, as it was still at planning stage.

9.2.11 Effective use of larvivorous fish viz. *Gambusia affinis* or *Poecilia reticulata* as the case may be (former in clear water and later in polluted water) should be made as biological control agent in water bodies which otherwise cannot be drained.

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ALTERNATIVE ANSWERS

Community-based Malaria Control in India

V.P. Sharma

India launched its National Malaria Eradication Programme (NMEP) in 1958, designed to interrupt transmission with residual insecticide spraying coupled with chemotherapy and anti-larval methods in urban areas. The strategy produced spectacular results. By 1965 malaria was reduced from around 75 million cases annually (with 800 000 deaths) to about 100 000 cases per year.

Unfortunately, even under the subsequent maintenance phase, malaria began to resurge in many foci, and in 1976 the NMEP reported 6.4 million parasite positive cases[1]. In this article, V.P. Sharma looks at some of the problems faced by the NMEP strategy, and discusses the alternative community-based approach now being evaluated in the northwestern state of Gujarat.

Malaria control in India is carried out by the National Malaria Eradication Programme, with costs shared equally between Central Government and the State Government Health Departments. The programme achieved striking success during the 1960s with a strategy of residual insecticide spraying supplemented by larvicidal measures in urban areas and chemotherapy to reduce morbidity from the disease.

During the 1970s, malaria resurged in India in a big way, with 6.4 million cases reported in 1976 (Box 1). At this time the eradication strategy was abandoned in favour of a revised strategy known as the modified plan of operation (MPO). Implemented in 1977, the MPO was designed to prevent mortality and morbidity due to malaria, protect the 'green revolution' and the industrial areas, and retain the previous achievements gained by the NMEP[2]. The MPO was a vertical,

Box 1. Resurgence of Malaria in India

After nearly a decade of successful vector control using residual organochlorine insecticides, malaria resurged in India during the 1970s, peaking at around 6.4 million reported cases in 1976. Some authorities suggested that this was mainly due to insecticide resistance associated with increased use of agricultural insecticides in the course of intensified agriculture. However, critical studies by Sharma and Mehrotra[1] revealed that malaria resurgence in India was not linked to any aspect of intensive agriculture, nor was it initially related to the development of insecticide resistance in the vector species. The studies found that malaria resurgence was attributable to four main factors:

1 *Shortages of DDT throughout the period of resurgence.* From 1958 to 1962–3, India received DDT under the US-AID programme, while local manufacturing capacity was developed. Subsequently, India purchased about 60% of the annual requirement of 9000-16000 metric tonnes, with the remainder to be locally manufactured. But imports faced delays and financial constraints, while local production was frequently interrupted. As a result, there was an annual shortfall of 13–34% of the required quantity.

2 *Persistent malaria foci.* In 96 spray units (localities designed to cover 1 million population) malaria transmission was never interrupted. In some, spray rounds were missed due to labour troubles, floods, drought, or DDT shortages. In others, malaria transmission continued even after 12–14 years of attack.

3 *Urban transmission.* Urban areas were not included in the original National Malaria Eradication Programme. Malaria control in towns was the responsibility of local authorities who were often ill-equipped, under-staffed, inadequately financed and without the necessary expertise for vector control. Mosquito larvicidal oil was often in short supply.

4 *Poor surveillance.* Eradication of malaria would only have been possible if, after elimination of transmission, surveillance was able to detect and treat residual and introduced cases. But in many areas, surveillance teams were not adequately staffed, trained or organized. Laboratory services were poor with huge backlogs of slides to be examined, and intervals of up to 4 months between case detection and treatment.

In their conclusions, Sharma and Mehrotra[1] comment on the false sense of confidence in the early 1960s that malaria was 'on its way out'. In 1963, the Malaria Institute of India was converted to the National Institute of Communicable Diseases, and even publication of the famous *Indian Journal of Malariology* was suspended. Research on malaria declined, and during the years of resurgence there was 'complete lack of information on the vulnerability of different regions of the country'. Now however, the Government of India is spending Rs 2000 million annually on malaria control (approx. £100 million), and there is an increasing commitment to enlist community participation in control activities.

centrally administered programme, which is gradually being replaced by the 'multiple purpose worker' scheme, and the 'village health guide' scheme under the general health services of the Ministry of Health and Family Welfare (Box 2).

The revised approach led to some improvement in malaria transmission, shown by the gradual decline to around 2 million reported cases in 1983. But since then, malaria cases have remained at about this reported level, and even this is probably a gross underestimate of the true incidence[3].

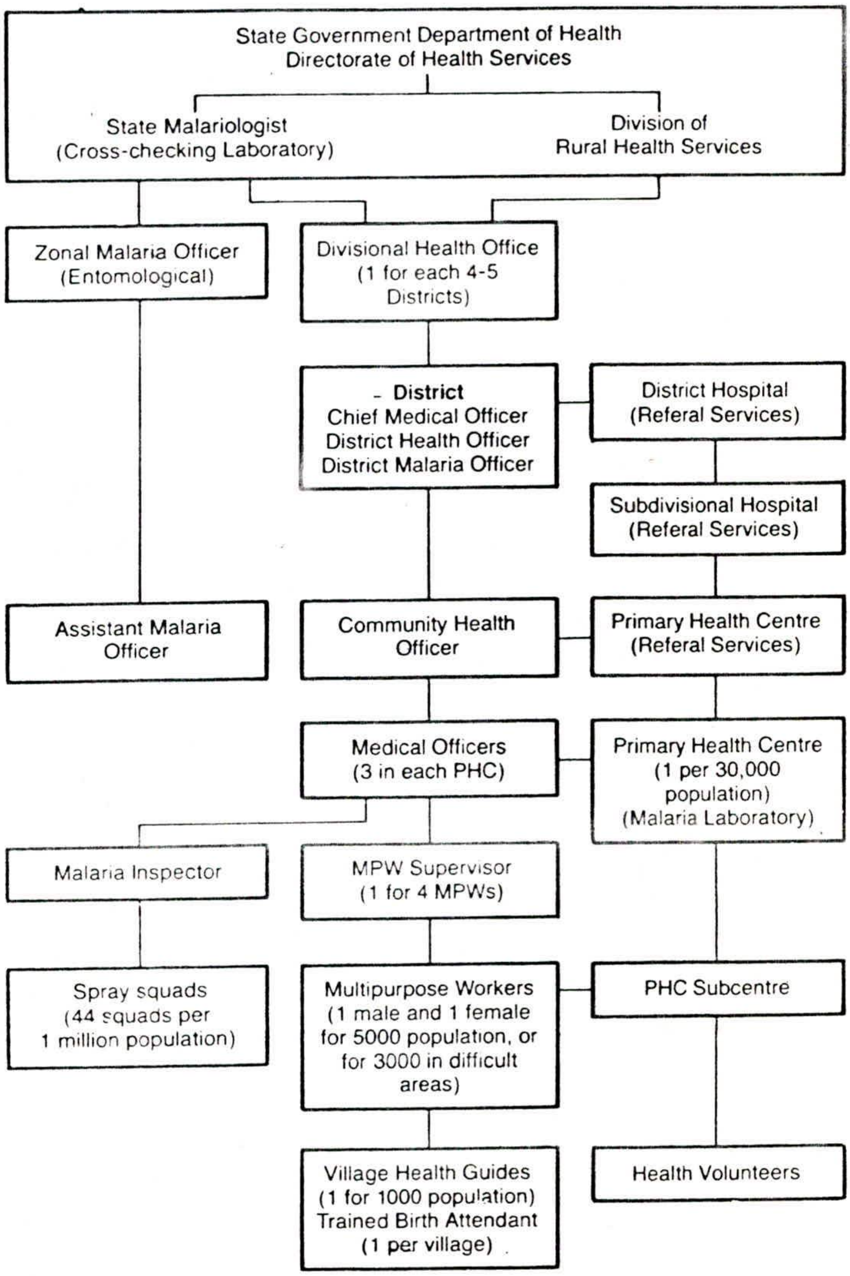
The MPO has faced many problems. About 30% of malaria cases in India are due to *Plasmodium falciparum*[4], which has become resistant to chloroquine in many parts of the country[5]. Alternative treatment schedules have been implemented in these areas, but focal studies show a considerable increase in falciparum malaria with fulminating epidemics resulting in reports of deaths in some areas. On the vector side, there are 9 vector species of *Anopheles* in India, with *An. culicifacies* the most widely distributed throughout rural areas[6]. This species has become resistant to DDT and HCH in most parts of the country, and is also resistant to malathion in the states of Gujarat and Maharashtra. Some of the other vectors are exophilic and avoid contact with sprayed walls.

But in addition to vector resistance, the strategy of insecticidal spraying now faces additional problems due to the reluctance of villagers to have their houses sprayed. The side-benefits of house-spraying, such as control of bedbugs and houseflies, are no longer appreciated by the villagers; indeed, soon after spraying with DDT the bedbug nuisance often increases – probably due to the excito-repellent action of DDT. There is also increasing concern about environmental contamination with pesticides, and spraying is not accepted where there are cottage industries such as bee-keeping or silk culture. In some areas, the proportion of householders refusing to have their houses sprayed has become very high. One consequence is that an increasing number of cattle sheds are now sprayed, which can be counter-productive if it drives the mosquitoes away from the cattle sheds to the houses. There are other problems of financial, logistic and administrative nature (see Box 1), including difficulties in obtaining insecticides and even instances of malpractice with insecticides diverted to agricultural use.

The cost of spraying operations is alarmingly high. The Government of India is currently spending about Rs 800 million annually on malaria control alone (approx. £40 million); this represents

Box 2. National Malaria Eradication Programme, Multi-purpose Worker Scheme

India's National Malaria Eradication Programme (NMEP) was launched in 1958 as a vertical, centrally administered system. After initial success, control failures during the 1970s prompted a revised strategy known as the Modified Plan of Operation (MPO) which had redefined objectives to control morbidity and mortality due to malaria, rather than to aim for eradication. By 1978 however, following India's commitment at the Alma Ata conference to achieve 'Health for All by the year 2000', the programme adopted a national directive to integrate anti-malarial operations with the primary health care services. The Multipurpose Worker (MPW) scheme is the result, which is now being gradually phased in. Under this scheme, each village should have a trained birth attendant, with about one village health guide per 1000 population. These are assisted by health volunteers recruited through the local primary health centre. One male and one female multipurpose worker are then in charge of areas comprising 5000 people (3000 in difficult areas), with one supervisor for 4 MPWs. Amongst their tasks, MPWs implement malaria surveillance and chemotherapy, reporting through their supervisor to the local medical officer. The MO can respond through a malaria inspector in charge of 44 spray squads per 1 million population. Thus, although the organizational structure has changed, the basic control strategy remains similar.



Organization of the Multipurpose Worker (MPW) scheme including malaria control under the primary health care (PHC) system.

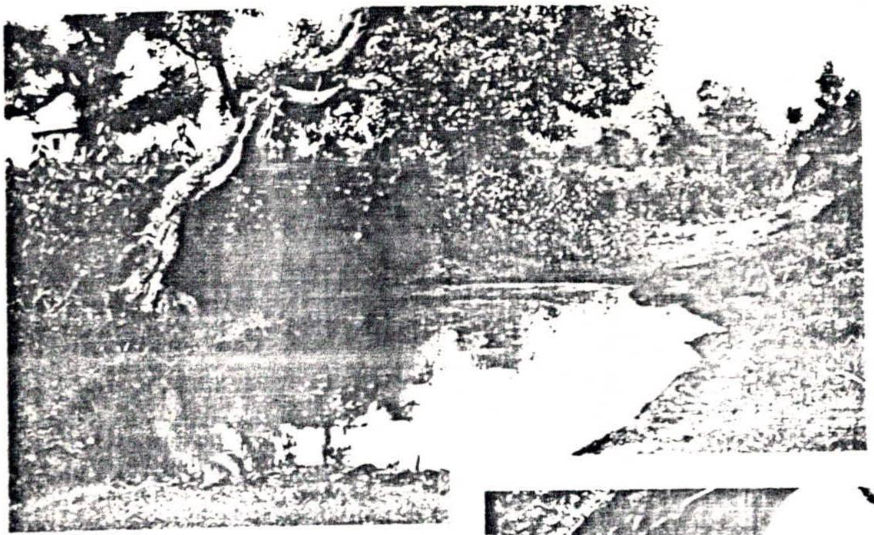


Fig. 1. To control mosquito breeding in ponds, larvivorous fish (Aplocheilus sp.) are introduced and the margins periodically cleared of aquatic vegetation.

Fig. 2. Mosquito breeding in wells and pits can be controlled by adding expanded polystyrene beads which form a lasting mat over the surface. The mat quickly reforms if the surface is disturbed.

Fig. 3. School children participate in voluntary work to fill in borrow pits where rainwater collects and mosquitoes can breed.

about 45% of her total health budget, and is to be matched by a similar amount from the State Governments. Many States find it difficult to provide the matching grants, causing local malaria control to be suspended pending the availability of funds. Yet the epidemiology of the disease is such that, if control is neglected for a year or two, it may assume epidemic proportions. But outbreaks of malaria have occurred even in areas where spraying operations have been continuous – making the cost-effectiveness of these operations quite questionable[7–9].

A Crisis waiting for an Alternative

Over the last few years there seems to have been no true decline in malaria transmission even though the Government is doing almost everything possible. Malaria control in India is in a state of crisis waiting for some alternative to emerge.

The philosophy of malaria eradication using residual [illegible] sprays and chemotherapy [illegible] to destabilize two components of the malaria triangle' (i.e. vector and [illegible]) without involvement of th[illegible] [illegible]ponent – man. This strategy [illegible] on two assumptions: (1) [illegible] [illegible]ying would kill the vectors [illegible] their life-expectancy below [illegible] would allow development [illegible] parasite, and (2) drugs would [illegible] parasite from the hum[illegible] [illegible] decades of [illegible] malaria operations have [illegible] by resistance of all three co[illegible] of the triangle: physiological resistance of the vectors, drug resistance by the parasite, and resistance to spraying by man. But it is possible to tackle this three-cornered resistance by using integrated bio-environmental control methods.

Bio-environmental Strategy

The bio-environmental strategy envisages primary emphasis on man who, in the form of the community, helps to fight the other two components – parasite and vector. The agency responsible for spraying assumes responsibility for mobilizing local resources and social willingness to control transmission. Instead of spending money on insecticides, local technologies are developed and applied to manage the environment to make it inhospitable for vector multiplication. This strategy brings about semi-permanent ecological changes, but, unlike insecticidal spraying, the bio-environmental methods do not affect the longevity of mosquitoes. Two factors therefore assume high importance; elimination of the parasite from the community by treatment of parasite-positive cases, and suppression of vector populations through rural development. In this way, control of the disease is not seen as an end in itself, but represents an entry point into the rural development process. It is essential that the vector control activities become an integral part of community development, so that these activities will be maintained even when vector populations are substantially reduced. If not, people can loose interest in vector control itself, and become vulnerable to sudden epidemics through loss of immunity combined with a few introduced malaria cases and sudden spurt of vector populations.

Demonstration in Gujarat

A demonstration and feasibility study of this approach was launched in 1983 in Nadiad taluka in the Kheda district of Gujarat state. Malaria is endemic to this region; Kheda district had the highest incidence of malaria for several years, and Nadiad taluka was the worst affected area with a high incidence of falciparum malaria resulting in several deaths. Mosquito breeding sites were innumerable, and insecticide spraying was not producing a tangible reduction in transmission.

The bio-environmental strategy consisted of seven components:

1 Reduction of breeding sites by minor engineering works
2 Elimination of breeding sites by physical barriers
3 Biological control of vectors, e.g. using larvivorous fish
4 Health education
5 Community participation in control activities
6 Chemotherapy of parasite-positive cases
7 Environmental improvement and income generating schemes

Intensive surveillance and prompt treatment of cases was the first line of action. This reduced morbidity and eliminated mortality from malaria, and also infused tremendous confidence in the villagers. Also, elimination of many breeding sites reduced the mosquito populations so that villagers felt less mosquito nuisance. A series of lectures in schools and community centres helped to inform the communities about our activities, and encouraged them to help and participate.

All water collection sites that could support mosquito breeding were surveyed and mapped. Simple methods were used to eliminate mosquito breeding, such as turning pots upside down, covering water receptacles, and filling borrow pits with soil. Mosquito breeding in ponds was reduced by introducing guppy fish (*Aplocheilus* sp.) which were collected locally and bred in abandoned cement tanks and ponds. We estimate that guppies grown in 20 village hatcheries can produce enough fish for the whole taluka of 100 villages. Vegetation in the ponds is cleared periodically to allow the fish to reach the grassy margins which are the most common mosquito breeding sites (Fig. 1).

Wells that were not used regularly were another source of mosquito breeding, especially of *Culex quinquefasciatus* and occasionally *An. culicifacies* and *An. stephensi*. In many of these we introduced expanded polystyrene (EPS) beads which form a lasting mat over the surface to prevent access by ovipositing female mosquitoes, and to prevent the larvae from breathing[11-13] (Fig. 2). In some of the least-used wells we introduced guppies.

For more substantial tasks, such as filling in and levelling borrow pits and other depressions where water collected, the community organized voluntary labour groups (Shram Dans) (Fig. 3). These groups are now equipped with 4 tractors to help level the land around villages. In addition to controlling anopheline mosquitoes, the surface drains and pits where *Cx quinquefasciatus* breeds were also cleaned and emptied. Many are now being replaced by soak pits.

Income-generating Schemes

It was realized that as the incidence of malaria and mosquito nuisance went down, the villagers may loose interest. Thus to sustain interest and to boost village economy, schemes of composite fish culture, social forestry and improved stoves are being encouraged as part of village development. Composite fish culture – rearing edible fish with the larvivorous fish – has been particularly successful. In the first year, income generated by edible fish rearing in 8 ponds was 100 times that earned normally, even when three ponds dried due to drought. The culture and sale of edible fish is now being extended, and could make the community malaria control activities completely self-financing.

The social forestry scheme also has a dual role. Eucalyptus has been planted in low-lying marshy areas to dry the land and prevent mosquito breeding. Large scale plantations are also being developed in unused waste land around each village. Demand for this has exceeded the availability of young trees, so village council-nurseries are being encouraged which also allow villagers to plant trees of their own choice. The tree plantations will become an important source of income, and we estimate that the annual earnings from social forestry in this region will eventually cover the cost of other malaria control activities by a factor of five.

The original demonstration area (complex A) covered seven villages with a population of 26,000. Because of the spectacular success of the malaria control activities, the project was extended to 14 more villages in 1984 (complex B) and a further 79 villages in 1985 (complex C). The total of 100 villages has a population of around 350 000. Results in the entire area have been most encouraging with a general improvement in the environment and enhanced awareness about malaria and methods for its control. Vector incrimination was not done, but populations of the two suspected vectors – *An. culicifacies* and *An. stephensi* – have declined to very low levels. Malaria cases have declined in complex A over three years from 411 to 61, in complex B from 143 to 70 over two years, and in complex C from 906 to 485 in one year. In contrast, nearby areas under insecticidal spraying have shown high vector densities and a rise in malaria transmission, particularly of *P. falciparum*. By 1987, we hope to extend the project to cover other areas with a total population of about 1 million.

Cost estimates suggest that to control malaria in the entire rural population of Kheda district (population 2.7 million) the cost of using DDT, HCH or malathion would be Rs 9.2 million, 10 million or 53.7 million respectively (£1 = approx. Rs 20). This compares with Rs 8.5 million by bio-environmental methods[14]. Moreover, the bio-environmental approach has many other advantages, especially in generating local employment and providing a sustainable economy. Imports are not required, the strategy is socially acceptable and can improve the local environment, and it can also reduce the incidence of other diseases. They key however, is that it addresses malaria within its local social context, and places disease control alongside the other priorities of village life.

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ENGINEERING ASPECTS OF MOSQUITO CONTROL OPERATIONS IN URBAN AND PERI-URBAN AREAS (REGULATION OF WATER RESOURCES, SURVEYS AND DESIGN AND LAND DRAINAGE, FLUSHING SYSTEM AND MAINTENANCE)

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1. Introduction

It was Sir Roland Ross in 1899 who first enunciated a theory that malaria could be controlled by control of mosquito population through reduction of breeding places. General William Crawford Gorgas (1910) demonstrated the validity of this theory at the beginning of the twentieth century when he achieved control of yellow fever in Cuba through measures directed against the vector, Aedes Aegypti. Gorgas also reduced the malaria rates in Havana through anopheline control and subsequently gave a dramatic demonstration of the possibilities of this type of sanitation in connection with the construction of Panama Canal. As early as 1902 in Malaya a simple method of drainage reduced the number of deaths in two small towns from 582 in 1901 to 144 in 1902; Sir Malcolm Watson (1910) proved the value of drainage and site selection as two important approaches for prevention of malaria in the same country.

Since the time of Ross's theory (1899) to the time of discovery of DDT and its commercial availability in 1940's, the main attack on malaria and other mosquito borne diseases was through adoption of established Engineering methods of reducing mosquito populations, such as regulation of water resources, source reduction by drainage, filling, dyking, flushing etc. along with chemical control by the use of larvicides. But with the advent of DDT and other more powerful insecticides, the emphasis altogether shifted from an environmental approach to a chemical approach. Both during the period of Malaria Control in 50's and during the period of global malaria eradication in sixties, extensive use of insecticides was made to break the chain of transmission, and by 1965 this approach almost achieved malaria eradication but thereafter deterioration set in. There have been alarming resurgences of malaria in some parts of the world since 1975 particularly in south Asia and India. In 1975-76 one in every one hundred Indians was found to have malaria. Causes for comeback of malaria are many and complex. But among them are, insecticide resistance of mosquitoes, their capacity to modify their ecology and biology when faced with adverse conditions, changes in the ecology and environment of areas due to development schemes, resulting in change of vector species etc. which have added a new dimension to the problem of malaria and other mosquito borne diseases today. Because of these and other difficulties, it appears that a reappraisal of well established permanent engineering methods such as regulation of water resources, source reduction, naturalistic methods, flushing and sluicing, land drainage, and ecological management etc., is urgently required. Since recurrence of malaria is more in the urban town and peri-urban area than in rural areas, these methods are more appropriate today than before for the control of mosquitoes in urban and peri-urban areas. Chemical weapons may fail due to mosquito resistance and drug resistance but Engineering methods if properly designed and conducted and well maintained will ensure a constant degree of success. Hence it is the purpose of this paper to review the Engineering methods available for mosquito control in urban and peri-urban areas, so that more and more of these methods could be used to control mosquito borne diseases, now and in future to compliment the recurrent measures. Anti-malaria/mosquito engineering is a special technique based on detailed knowledge of habits of mosquitoes, and it is one which all development engineers, Sanitarians and those responsible for control of vector borne diseases, including laymen should learn. Successful application of the techniques calls for a close collaboration between P.H. doctors and Engineers. Public cooperation is an undisputed factor in proper implimentation of antimosquito works.

2. Breeding places in Urban and Peri-urban areas

Water resources favourable for mosquito breeding may be natural or man made. Natural water resources in urban areas are (i) a river or stream with sluggish or intermittent flow in the vicinity of the town, (ii) natural lakes or ponds, (iii) low-lying areas flooded during monsoon, (iv) marshy and swampy land in and around the town due to ground water seepage. Man made water collections are: (i) water logging due to obstruction of runoff by railway or roadway embankment with inadequate capacity in culverts, and other cross-drainage works, (ii) borrow pits dug for construction of embankments for roads, railway, canals and other construction works, (iii) ill maintained swimming pools, (iv) overhead and underground storage tanks uncovered, (v) abandoned brick fields and quarry pits, (vi) abandoned wells, cisterns, cattle troughs and garden-pools, (vii) vent-pipes of septic tanks and of pit-privies without mosquito nets, (viii) gulley pits of underground storm-drainage silted, (ix) service privies and accompanying cess pools, (x) open surface sullage drains in medium and small size towns with stagnant sullage and sewage, (xi) nikasi drains and canals with sluggish flow of polluted water and with growth of algae and water hyacinth, (xii) indiscriminate digging and dumping for laying of water-mains, sewerage, underground cables, construction of metro-system, creating many temporary or permanent water collections, (xiii) insanitary cattle sheds inside the towns, (xiv) curing of concrete floors holding water for 3 weeks (xv) small water collections in private premises in discarded earthen pots, cigarette tins, flower vases, overhead cisterns, roof-gutters etc.

Besides, in some periurban areas, storage reservoirs for water supply and irrigation, canals, flood irrigation in the vicinity of towns may also provide additional water resources for mosquito breeding. Uncontrolled sewage farming in the vicinity of some towns provides breeding places for Culex mosquitoes. Industries who throw out waste waters indiscriminately create stagnant pools of clean and polluted waters favouring mosquito breeding, both anopheline and culicine.

In general the breeding places in urban areas are so numerous that effective elimination of them will be an uphill task for the mosquito control squads. It calls for a close coordination between the various agencies of Government and municipal administration which are responsible for town development and services. Besides, public awareness and cooperation is absolutely necessary for an effective control programme.

3. Survey and Mapping

A prerequisite to any mosquito control programme is a malaria or filaria survey to assess the intensity of disease, and to identify the principal vector species and their breeding places. To help the malariologists and entomologists in conducting these surveys and also for carrying out subsequent antimosquito measures, a map of the area is absolutely essential. The existing town map and the topographic map of the area should be used as base maps on which additional data can be plotted. This makes possible maps of greater accuracy in shorter time than these produced by sketch-mapping. With the further advantage that since many of the principal landmarks such as railroads, highways, bridges, large buildings, low-lying areas, ponds, hills, ranges, storage-reservoirs, streams and canals passing through or near the town are found on these maps with sufficient accuracy, additional data regarding breeding places etc. may be added and oriented as required. If necessary the scale of existing map may be altered in a drafting room to a scale more convenient for field use.

When suitable maps and field equipment are not available, sketch maps should be prepared. Although lacking in accuracy, sketch maps are adequate as preliminary maps and can be prepared with minimum expenditure and time. Later as information of greater accuracy becomes necessary, more refined methods of mapping can beused, if needed.

Although contouring is essential for drainage of marshy areas and water-logged areas, contouring need not be undertaken in the preparation of preliminary sketch map, which should be developed to bring out the following pertinent basic data:

a) Main highways, rail-roads, bridges, streams, canals, principal buildings, dwellings.

b) All actual or potential mosquito breeding areas. These water resources should be measured and delineated as accurately as possible including ponds, cesspools, lakes, swamps, seepage areas, wells, canals, principal drainage channels and any other natural or artificial bodies of permanent or semi-permanent water which are actual or potential breeding areas lying within the flight range of the centres of population.

c) All potential drainage outlets should be accurately located and indicated on the map to assist in planning progressive elimination of water collections by drainage. Such outlets include streams, large canals, drainage channels, creeks and the gulf or ocean.

d) At times it may not be feasible to locate every house in an urban or peri-urban area on the map, although it is absolutely essential to accurately define the boundaries of the areas to be protected. The equipment needed for making sketch map include a plane-table with alidade, a compass, drawing paper (preferably square paper) and a pencil. Horizontal distances to the objects from the point of reference can be measured by 'pacings' for walkable distance or by a milometer if an automotive vehicle is used for long distance measurements. A pace is defined as the distance from the heel of one foot to the heel of other foot walking naturally. A stride is equal to double the space. For quick plotting of distances on the map, a Pace scale chart can be prepared and used. Long distant objects not easily accessible for pacing could be located on map by the method of intersections. The sketch map should cover essential details. Unwanted details will obscure the map. The sketch should be accurate and as complete in detail as time permits. A legend to the map should be given.

If the town plan has already got contours, there is no need to carry out a levelling survey in the whole area. But levelling will be required for antimosquito drainage schemes, for preparing accurate longitudinal sections along the alignment of drainage channels to the points of discharges. The wellknown techniques of levelling should be used by using dumpy or Wye levelling instruments, levelling staff, chain and arrows etc. The plotting scale for the sketch map should be so chosen as to permit an optimum size of the map for ease of handling in the field. Generally a scale of 1 inch equal to 800 ft. or 1 inch equal to 1600 feet should be satisfactory.

Besides location and delineation of public breeding places during the survey and preparation of sketch map, in cities and municipal towns it is also necessary to make a house to house survey to locate cesspools, cisterns, empty containers, household septic tanks etc. which are potential breeding places.

Once the sketch map is ready with all existing and potential breeding places identified and located, the next step would be to choose suitable methods of elimination of breeding places or prevention of breeding in those water collections. This is the most vital step in anti-mosquito operations. Both the entomologists, malariologists and the engineers who design and execute the anti-mosquito methods should discuss and make judicious choice of methods for each situation. The methods chosen are mainly guided by the type of mosquito species, prevalence in the locality, their habitat and ecology, besides other important factors such as cost, case of operation and maintenance and the time involved. A wrong choice may adversely affect the situation leading to breeding of mosquitoes which was hitherto absent. For example, in foothill areas most swamps are harmless, but if drains are dug through them these often become dangerous breeding places owing to a particular species, *A. minimus*, that breeds in drains.

Digging of drains has been the cause of many outbreaks of malaria in such regions. On the other hand in plains, most pools, swamps, marshes as a rule are sources of breeding and they should be drained or filled. Another example of a species specific method is in the case of A.maculatus of Malaya. Although river training eliminates other species like A.minimus and A.fluviatilis which are breeders in running water, this method will have no effect on A.maculatus as it is a breeder in faster-running streams. The method of choice in this case is subsoil drainage. Cutting down of jungle and other vegetation is the choice where the vector species in the area prefers to breed in dark and shady areas. But certain other species like A.maculatus and A.minimus in Assam prefer breeding in places exposed to sunlight. Indiscriminate removal of jungle in the areas where such species exist may have disastrous results. In Assam where A.minimus is the carrier species, growing of shade-giving trees over the streams, drains, swamps, has been the adopted practice in certain tea estates with positive results.

4. Methods of Engineering Control

Several methods of Engineering Control of mosquitoes are available. They may be broadly classified as:

(1) Drainage
(2) Filling
(3) Training and Channelisation
(4) Flushing or sluicing
(5) Dyking and dewatering
(6) Pumping
(7) Filling and deepening by mechanical means
(8) Clearing of vegetation, floating debris and aquatic plant growth control
(9) Water level management of storage reservoirs
(10) Water level management in irrigation
(11) Other naturalistic methods
(12) Jungle clearing and shading.

Although all these methods are applicable in both urban and rural mosquito control programmes, some have a wider applicability in urban than in rural. Methods like drainage, filling, channelisation, flushing, pumping, clearing of marginal vegetation are more widely used in urban and peri-urban areas than water level management of storage reservoirs and irrigation systems. Some of naturalistic methods are also useful in urban mosquito control. Hence, further detailed discussions are restricted to only those methods which are more applicable to urban situations in addition to other special measures required for urban mosquito/malaria control.

Gmarayel ...

-.1 Drainage

4.1.1 Types: Drainage is essentially a means of removing water in order to prevent mosquito breeding. Natural or man-made obstructions to flow of rainwater causes water collections and creates conditions favourable for mosquito propagation. Natural barriers across rivers, tortuosness, overgrowth of jungle, lack of adequate gradients in streams, impervious subsoil causing marshes, ponds etc. are examples of natural barriers. Man made barriers are roads, railways, canal embankments built without adequate waterways for cross country drainage, drains, bunds for water supply and hydroelectric power, high sills of culverts and bridges, excavation of borrow pits, brick fields, quarry pits and a host of other man-made water containers as briefly mentioned in an earlier paragraph,in urban areas.

Drainage to control mosquitoes differs from problems of storm drainage. Object of the former is only to facilitate flow of water under conditions which will prevent the breeding of mosquitoes prevalent in the area. If the drains carry water fast enough to prevent breeding and will prevent the accumulation of water for more than one week it is sufficient. Storm drains on the other hand are designed to carry the maximum expected floods in a day or a few hours. Storm drains are larger, more expensive and do not cater for conditions of dry weather flow which will cause breeding of mosquitoes. Another type of drainage is in irrigation. The objective of this drainage is to intercept the excess water fed on to irrigated lands, carry it off fast to drain the land quickly, and reuse it or discharge it to a natural water course. Here the design of drainage is mainly guided by anticipated excess water flow over the land and high velocity needed to drain the land so that crops are not affected adversely.

Drainage projects should be undertaken only after careful survey and planning by Engineers and Sanitarians with the help of malariologists. Drainage may be accomplished by the use of:

(1) Surface drains or ditches
(2) Subsurface or subsoil drains
(3) Contour drains
(4) Vertical drainage
(5) Lido Drainage
(6) Fascine subsoil drains.

The choice of any type depends on local factors such as topography, contours (gredients), soil, climate and rainfall as well as economic factors.

4.1.2 Surveys: The first and foremost thing to be done in a drainage project is to conduct a drainage survey. Before undertaking a detailed engineering survey a thorough reconnaissance of the area should be made. This is very important and should never be omitted as it enables the designer to determine what kind of survey to be made, where it should begin, and how it should be conducted. During this preliminary reconnoitory survey data should be collected on the following aspects:

(i) Location of breeding areas and their character.

(ii) Sources of water, e.g. runoff from catchment, irrigation, seepage, etc.

(iii) Approximate population living within the mosquito flight range.

(iv) Type of soil and characteristics of trees and vegetation on the proposed alignment of main drain and branch drains.

(v) Whether or not a suitable outlet is available. While conducting the reconnaissance, the surveyor should contact local residents who will be of much help in locating drainage outlets and describing flow characteristics of receiving streams i.e. HFL etc. so that he could judge whether the outlet would be able to discharge into the receiving stream without causing surcharge of outlet channels.

All collections of water actually or potentially capable of breeding mosquitoes should be accurately located on the map as already described in a preceding paragraph, with their size delineated and their position established with respect to habitation. Sources of water should be identified. Whether it is a runoff due to direct precipitation or runoff from an adjacent area, or flow from an irrigated land or seepage of water from ground water source should be carefully investigated. Estimation of flow from the first two sources are simple. Wellknown rational methods may be used to estimate runoff from the drainage area. Similarly irrigation water carried through pipes and channels may easily be estimated. But it is more difficult to determine the direction and quantity of ground water flow to be intercepted by drainage to lower ground water table and to estimate seepage. Seepage outcrop is due to an inclined water bearing pervious stratum lying immediately above an impervious stratum. Direction of flow can be determined by digging test holes down to the water-table and conducting a fluorescent dye test; the discharge can be measured by digging a cross-ditch along the toe of the slope of hill, deep enough to intercept seepage outcrop and measure the flow. In case of large swamps and seepage areas, it is necessary to dig a series of test holes spread over the whole area on a grid system, and to measure the distance to the water table at different seasons; the layout of a surface or subsoil drainage network should be determined. Location of possible outlets for low lying areas is important. If drainage cannot be provided by simple gravity drains, pumping has to be resorted to. In most of the coastal towns and even in some towns by the side of a river or stream such a problem exists, the only alternative to gravity drainage being to resort to pumping at least during the monsoon period. The level in the flooded river may rise above the level of low lying areas of the town requiring not only pumping of water from the city drainage system, but also protection of town from flooding by raising of embankments. Borings along the proposed centre line of drains will be required to indicate the proper slopes for side embankments, the optimal type of lining of sides and bottom, and the level of the ground water table, which in turn will determine the effect of drainage on agriculture.

Once the preliminary survey is completed, a detailed engineering survey should be undertaken and the system of drainage designed.

4.1.3 Design Criteria:

Drainage for mosquito control must be designed to carry water with a velocity sufficient to prevent breeding of various local species. *A. maculatus* can stand higher velocities, while *A.culicifacies* is not able to breed in channels with clean margins in which the velocity of flow is more than 1.5 feet/sec. A minimum velocity of flow 2.0 feet per sec., which is also the minimum self cleansing velocity for suspended solids, is satisfactory from the point of view of mosquito breeding. If the drainage carries storm flows, then maximum velocity at peak flow should not be high enough to scour the channel. The drains are designed as open channel flow so that (i) the bottom is low enough to drain the wet area, (ii) the capacity is sufficient to carry the water brought into it (iii) the velocity of flow should be within limits as discussed above, (iv) the sideslopes are such that the banks will not slide or cave. The elevation of the drain bottom is determined by ground surveys of the area to be drained, in relation to the possible outlets.

The carrying capacity of a drain is based upon the maximum runoff of the area and the rational method of estimation of runoff.

$$Q = CIA$$

is used for this purpose where

Q = Runoff in cubic feet of water per sec.

C = Runoff coefficient value of C. ranges from 0.10 for flat areas and highly pervious soils, to 0.40 for small agricultural watersheds in rolling terrain, to 0.95 for city pavements and roofs.

I = Rainfall intensity, in inches per hour.

A = Watershed area, in acres.

(Note: that "I" should be determined by study of previous data on intensity and duration of rainfall in the area, and by drawing the intensity-duration curves and choosing a storm frequency of twice a year to once in two years depending on the importance of the area flooded. Commercial areas should be subjected to less flooding than dwelling areas.)

The channel capacity is given by basic Chezy's formula.

$$Q = A.V.$$

Q = Discharge to be carried, in cubic feet per sec.

A = Cross-sectional area of channel, in square feet.

V = Velocity of flow in feet per sec. = $C\sqrt{rs}$

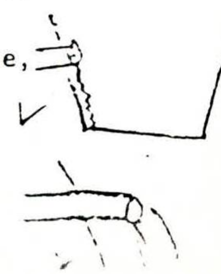
(Note that velocity of flow depends on the hydraulic radius 's', the surface slope or fall per foot, and 'C' a Coefficient. 'C' can be worked out from Kutter's or Manning's formula. The gradient to be chosen is guided by the natural slope of the land. The desirable minimum grade of a drain varies with many hydraulic factors, most important being the volume of flow and hydraulic radius.)

4.1.4 Surface Drains:

Open or covered surface drains are extensively used both for storm and antimosquito drainage.

4.1.4.1 Earthen drains

For antilarval efficiency open earthen drains (Kutcha drains) should be narrow and deep (1'-2' width is sufficient in most cases) and not broad and shallow. The gradients suitable for small earth drains are 1 in 50 to 1 in 200. Gradient suitable for large earthen drains is 1 in 200 to 1 in 1000. Width of drain is bottom width or width of invert. Side slope of earthen drains should be steep enough to stand by its own angle of repose i.e. 1 to 1 or 1-1/2 to 1 for loamy soils, stiff clay 1/2 : 1, and sandy soils 4 to 1. Turfing is necessary on earthen slopes to prevent scour. The spoil should be thrown at least 3' away from edge of the drain and should not obstruct natural drainage; it should preferably be used for filling, or may be spread and gently sloped. If stacked as soil banks, passages should be left through which surface water can flow into the drain. Scupper drains are put in wherever there is a cross drainage to be made. At the junction of scupper drain with main drain, stone pitching and training on the sidewalls should be done to prevent scour. Joining of two drains should never be at right angles as erosion and sand shoals will result. They should join at an acute angle. The nose of the junction should be protected by pitching of stones or concrete. Eddy formation is to be prevented where pipe drains join an open drain. The outlet should conform to the side slope of an open drain. Wherever there is a change from a steeper gradient to flatter one,



silt will be deposited in concrete channels. Sand traps are to be provided by making an excavation (10-15' in length) deeper by about one foot than the rest of the length of the drain, When the ground falls steeply, it may be necessary to reduce the gradient of the drain to prevent erosion. This is accomplished by a series of drop walls. Aprons are required to prevent erosion below dropwalls.

Cattle crossings should be provided in all earthen drains.

4.1.4.2. Lining of Earth drain

Lining of drains is a useful measure to prevent the erosion and scouring frequently seen in earthen drains. A lined drain may require only half the cross section of an unlined drain with irregularity of cross section, and will save a great deal of maintenance, such as repeated regrading, cleaning and even oiling. Several types of ditch lining are in common use and the choice will depend on local conditions. The term invert is used to describe a section of durable ditch lining which covers the bottom and part of each side. Inverts may be cast in the drain itself. Precast inverts made of vitrified clay tiles, cement and concrete are more commonly used for quick lining. Brick or stone pitching with cement mortar jointing and pointing are also used. Wood is rarely used. Precast concrete inverts are becoming more and more popular.

4.1.4.3 Lined ditches are more durable, more easily cleaned, less in need of inspection, less likely to breed mosquitoes than unlined drains.

In urban areas unlined drains are not recommended. Only lined drains with brick or stone masonry side walls and concrete invert are suitable. As a rule the lining should be 'U' shaped with sloping sides. Sometimes it is necessary to extend the lining only a few inches above the nomal water line. It is usual to provide sloping seepholes in the sides and sometimes in bottoms of the lined ditches for entry of seepage water. When ground water level is high, the dry joints of precast inverts allow seepage to enter the drain. The bottom lined drains should have in the bottom a central narrow channel as a subditch or cunette to take the dry weather flow. Best suited shapes for surface drains are rectangle, trapizoidal, semicircular, semi-peg top and ovoid. For inverts, semi-circles of 3" to 18" diameter are commonly used; 'V' shape is unsuitable as it leads to clogging and presents difficulty in effective cleaning. Digging and construction of a drain should start from the lower end of drainage as it can function from that instant. But in cleaning an old drain the work should start from the upper end.

4.1.4.4 Digging of drains

In a large drainage project manual digging may be replaced by machine digging for economy and speed of work. Many types of trench excavators, such as dragline and chain excavators, can be used.

4.1.4.5 Blasting

Blasting of open earthen drain in wet or marshy ground and through heavily wooden swamps is the least expensive method of excavation. To the mosquito-control engineer the blasting method is particularly valuable, as it is the quickest known means of constructing open earthen drains for drainage of marshy land and good progress can be achieved. A crew of 6-8 men skilled in blasting can ditch about half-a-mile a day. Nevertheless it is a specialised job and calls for an experienced blaster to supervise operations. Blasting is not advocated in the habited areas.

4.1.5 Surface drainage in Urban areas

In many medium sized and small towns, surface drains are the only drains provided for drainage of storm runoff. The drains are generally lined, but kutcha drains are also constructed in many parts of the town due to paucity of funds. These drains get filled up with silt, clay, waste construction materials, refuse etc. and gradually fail to carry the flow and forms pools of stagnant polluted water, which are ideal for mosquito breeding particularly of Culex. The drains are neither cleaned of clogging debris nor maintained in good repair by the municipal authorities for want of funds. The outfall nallah is generally a nikasi drain, silted and overgrown with weeds and vegetation, and leading to stagnant cess pools.

For prevention or reduction of mosquito breeding in these drains it is necessary to clear them completely, and repair and reset them to proper grade and alignment providing a cunnete for dry weather flow. Cess pools should be drained, and a proper outfall drain made with a well-designed and constructed discharge outlet into the receiving stream. In addition, broken culverts need to be re-constructed.

4.1.5.1 Contour drains on hill slopes are useful in dealing with seepage water but it is necessary to treat them systematically with larvicides.

4.1.6 Sub-Soil drains

Sub-soil drainage in mosquito control projects is adopted for the following situations:

(a) As an alternative to surface drainage in flat lands, in order to lower the ground-water table so that surface pools are more readily absorbed into the ground.

(b) To intercept seepage outcrops, and drain marsh lands and swamps.

(c) To deal with hill streams in ravines.

(d) In agriculture to save land which otherwise would have been occupied by open drains.

Four types of subsoil drainage layouts are commonly used (see Fig. 1).

(i) Random system: Used for draining low narrow depressions The lines of pipe follow the lowest portions of depression.

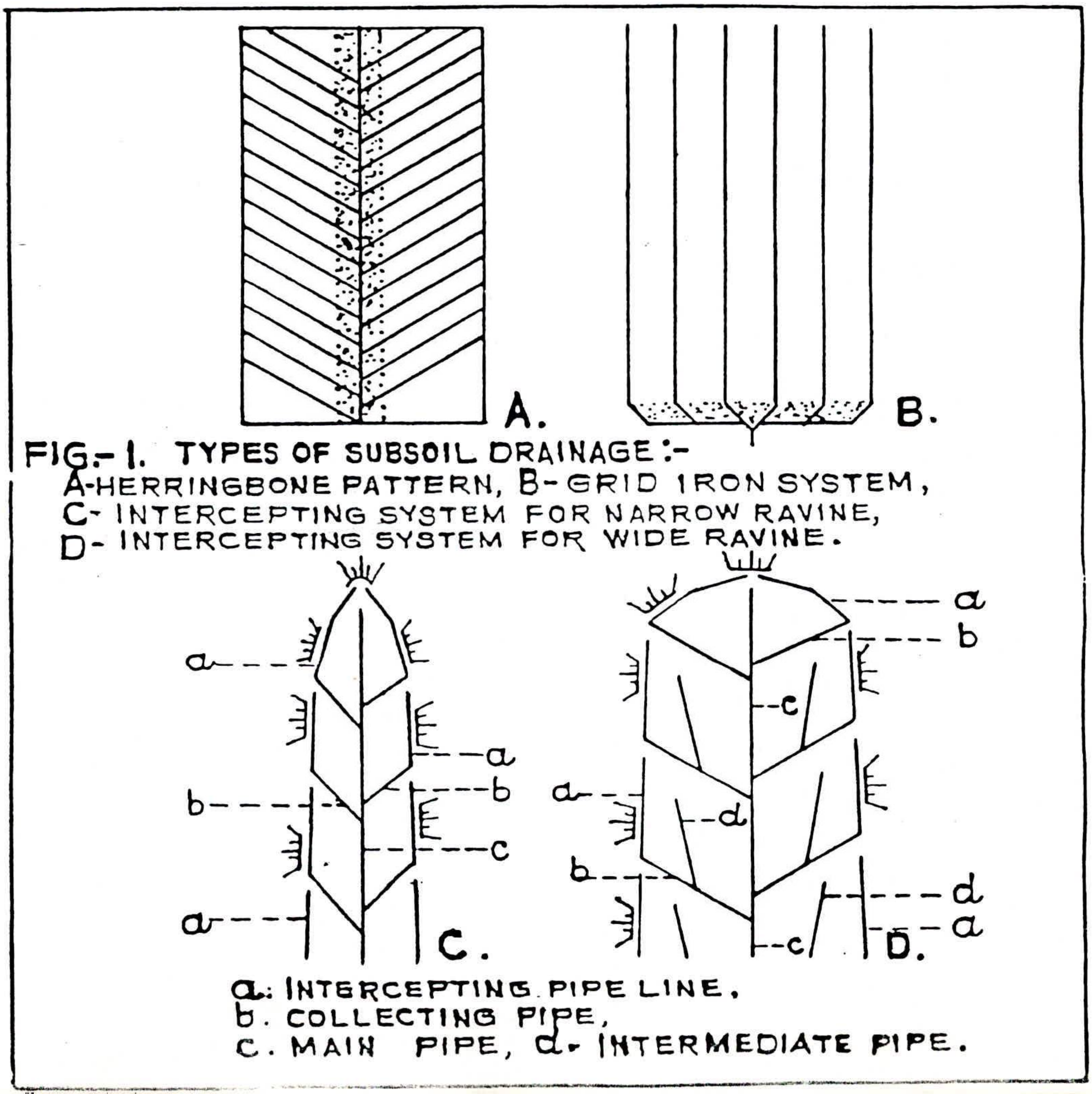
(ii) Grid-Iron system: Economical for flat lands of uniform slope. It has a mainline running along the edge of a field with a system of long parallel laterals entering at an angle of 45°. Sometimes it includes a sub-main channel.

less junction

(iii) Herringbone system: The main is laid in the lowest part. Laterals enter the main at an angle of 45°, offset.

(iv) Intercepting system: This is used to intercept and remove hillside seepage before it can move out upon flat or depressed land below.

FIGURE I



Just as in surface drainage schemes, preliminary studies should be made to ascertain characteristics of soil, level of water table and sub-surface configurations in order to work out proper design of the subsoil drainage system. In dealing with the problem of drainage of a seepage or swampy area in a ravine, it is first necessary to clear vegetation and dig contour drains from the lower end of the valley before laying sub-soil drainage. This will open up swamp spots, making breeding places clear. Further it will also remove the surplus water and therefore make working within the marshy or swampy area easier and aid in the task of laying subsoil drainage. In fact Hunter by his experience in subsoil drainage at Singapore suggests that first the ravine be provided with open drainage and oiling for some months before the subsoil drainage is installed.

The depth, gradient and spacing of lateral and main drains depends on soil permeability, water table level and the natural slope. In any case pipes should not be laid at depths shallower than 4 feet or they may be damaged or choked by entry of plant and tree roots. To lower the subsoil water a gradient of at least 1 in 400 is usually required. In sandy soil a gradient as steep as 1 in 100 for 4" pipe and proportionately less for larger pipes is required. To intercept seepage a gradient of 1 in 200 is recommended and sub-soil gradients steeper than 1 in 30 are not recommended. Similarly, the length of drains should not be excessive. The smaller the size the greater the friction loss. For example, a 4" pipe laid on a grade of 1 in 1500 should not be longer than 1500' whereas a 12" pipe laid on the same grade or even flatter could extend to a length of 5000 ft. Similarly, spacing of lateral drains depends on soil composition. Drains should be kept closer in clay than in sand or gravel. In a mixture of clay and fine sand with water table less than 5' the depth should be 6 feet below the surface and spacing should be 7' apart. In sandy soil with water table any distance below the surface, the depth of drain may be 4-5 feet and spacing 100-200 feet apart.

Subsoil drainage should discharge freely into streams or ditches. The outlet of a subsoil drain should be carefully constructed so that its outfall is free and does not create a mosquito breeding nuisance. On the other hand, Dr. J.W. Scharff who had a wide experience in antimalarial drainage suggested that the outlet need not necessarily be a free discharge all the time, as it will frequently result in having the pipeline laid at shallow depth; as a rule outlets should discharge with the lowest practical outfalls even if this means outlets are occasionally flooded. Drains are made of burnt clay, vitrified clay or concrete pipes of short lengths ranging in diameter 4" to 12". Trenches are excavated from the down stream end, levelled and pipes are laid loose jointed without any jointing material. The top semicircle on each joint is covered with palm leaves, rubber strips or kneaded clay to prevent water entering from top portion and the backfilling is done carefully and tamped. The topsoil should be replaced so that grass may take root over the pit. In loose soil, backfilling should proceed immediately after laying. The pipes should have a capacity to carry 4-5 times dry weather flow. As a thumb rule they may be designed to remove 1/4" to 1/2" of water.in 24 hours. No trees should be left within a distance of 40 feet of subsoil drainage lest their roots enter and block the pipes. Wells should be provided at suitable places to serve the threefold purpose of silt chambers, inspection wells and cleaning points. The minimum width of these wells should be 24" for ease of cleaning.

Several expedients can be used in subsoil drainage. They are (i) clay or concrete pipes filled with kneaded clay with covering over top and side of joints, (ii) Pipes covered with stones or gravel for extra permeability, (iii) Hard wood or hollow bamboo in place of clay pipes. No rain water or household sullage water should enter subsoil drainage. Where such a situation exists, a superimposed concrete channel for carrying sullage or rain water should be provided.

4.1.7 Fascine drains

These are a form of subsoil drains more adopted to rural conditions. Bundles of sticks 2" - 4" in diameter tied in bundles of 1'-4' diameter and 6-15'long are laid in excavated trenches with their buttends facing upstream. They may be supported every 4' on cross pieces of wood placed over short stakes and covered with earth. The low water which is favourable for mosquito breeding particularly anopheline will be taken underground, and the absence of light together with mechanical construction and pollution if any will inhibit breeding.

Subsoil drainage has been most effective in dealing with hill streams, seepages and swamps. But the cost is prohibitive. In case of plantations, the disadvantage is the removal of all trees in the vicinity of drainage to prevent choking with roots thus resulting in wastage of land. This together with heavy cost of maintenance resulted in the owners of many estates in Malaya abandoning subsoil drainage and reverting to open drains and oiling.

4.1.8 Vertical drains

When water is held on the surface by an impervious stratum which is overlying a pervious stratum like hard pan underlaid by sand, it may be more economical and effective to adopt a vertical rather than horizontal drainage. In vertical drainage a hole is bored through the impervious layer into the pervious layer so that water will drain into the pervious layer and be carried through it. It may or may not be necessary to line the vertical drain to prevent erosion. Screened drainheads are necessary to prevent entry of coarse material and debris. A situation where vertical drainage is feasible is a clayey top layer overlying a limestone stratum. Boring holes through the impervious layer may be done by hand-boring tools and machines or by dynamite. Gorman used dynamiting to drain a pond of 1800' x 50' vertically. The pond was in the centre of a city but its bed was several feet below the invert of the city sewer, and horizontal drainage in this case was difficult and costly. Stromquist drained a pond of 40 acres using a 7 ft. square shaft sunk to 40 feet lined with 2 x 6 inch timber double braced at intervals of 3' and with 2 x 12" sheathing. This type of drainage is useful if the geological formation is favourable, and it could be used for small collections of water. Collections in towns and cities caused by leaky public-water taps, pot-holes and road ruts in clayey soil which are a considerable source of mosquito breeding should be removed by short vertical drains or absorption wells filled with porous material. Before adopting this method of drainage, however, the possibility of ground water pollution should be critically evaluated.

4.1.9 Lido drains

Where conventional drainage cannot be provided on account of lack of funds, the method of Lidoing can be adopted in areas where rainfall is moderate and not high. It consists of excluding storm runoff over the area to be drained by cheap bunding and dressing the area so that all rain water will flow into a single depression which is sized to required capacity. All other pits in the area are filled. Thus area available for mosquito breeding is minimised and larviciding becomes easier and economical. The method can be applied to a series of burrow pits along the embankments of railways, roadways or canals, provided ground slopes are favourable. A chain of burrow pits could be interconnected to drain to the lowest pit which could be sized to collect all water drained from above; larviciding will then be cheaper and economical. But this is no substitute for excavating burrow pits in such a way that water does not collect and fill up the pits.

5. Filling

Filling to eliminate breeding areas can be adopted in a number of situations. Many of the land reclamation schemes in coastal areas have been the result of diverting the flood water bearing 16-25% of suspended silt on to low lying marshy lands, but it requires long range planning and continued mosquito control operations in the filled area till the level is raised and the silt laden liquid dries up to form dry land. Further treatment of shrinkage cracks developing in the reclaimed land will be necessary to eliminate breeding of mosquitoes.

Old quarries and brick pits can be silted up very cheaply by diversion of small streams. A marsh land in Assam was converted into sandy flat by diverting a silt bearing stream. Pools and shallows in stream beds can be filled up naturally by constructing groins.

Filling tree holes with earth, sand, gravel asphalt or cement prevents breeding in these small collections. Asphalt is probably the best for this.

Rock pools can be filled by cement to eliminate breeding. Moats in and around towns, small ponds and other low lying land which cannot be drained can be filled by city solid wastes through controlled tipping, taking care to see that all empty containers are crushed before filling or burial. This will result in reclaiming water-logged and waste land areas, and permit establishment of parks and playgrounds and even buildings after several years. Materials used for filling should be relatively porous, if possible, because if water retaining material like clay is used then any slight surface depression may hold back water long enough to breed mosquitoes. Brick pits are filled with earth. No brick factory or stone quarry should be allowed within a distance of a mile from habitation.

Burrow pits in and around the town should all be filled up. Burrow pits excavated for canal embankment can be filled by cutting earth from a field just above the dug area, lowering the level of the field thus not only eliminating the burrow pits but also increasing land under irrigation.

In all cases of filling it is important to level the surface so that no rain pools will form. Inert materials like waste building materials, solid industrial wastes, cinder and ash, saw dust etc. are more suited for simple filling and consolidation than organic refuse which requires sanitary land filling operation and control. A special method of reclaiming swamps is by hydraulic fill, high silt laden liquid being obtained by dredging operations in estuarine rivers subject to heavy silting.

6. <u>Stream Training and Channelization</u>

The purpose of stream training is to induce the fastest possible flow in the stream or river concerned. This measure could be adopted in relatively small streams which have a sluggish and intermittent flow and irregular cross section. River training consists of increasing embankment slopes to reduce area on side flanks exposed for water collections between HFL and LWL, improving longitudinal grade by removing such impediments as fish traps, boulders and brush from the water course, rebuilding cattle crossings, straightening streams and reshaping banks, besides dredging a shallow channel down the centre of the river bed. This will either cause complete drying up of many kilometers of sluggish or stagnant pools or restrict the water to a narrow central channel which could be effectively larvicided.

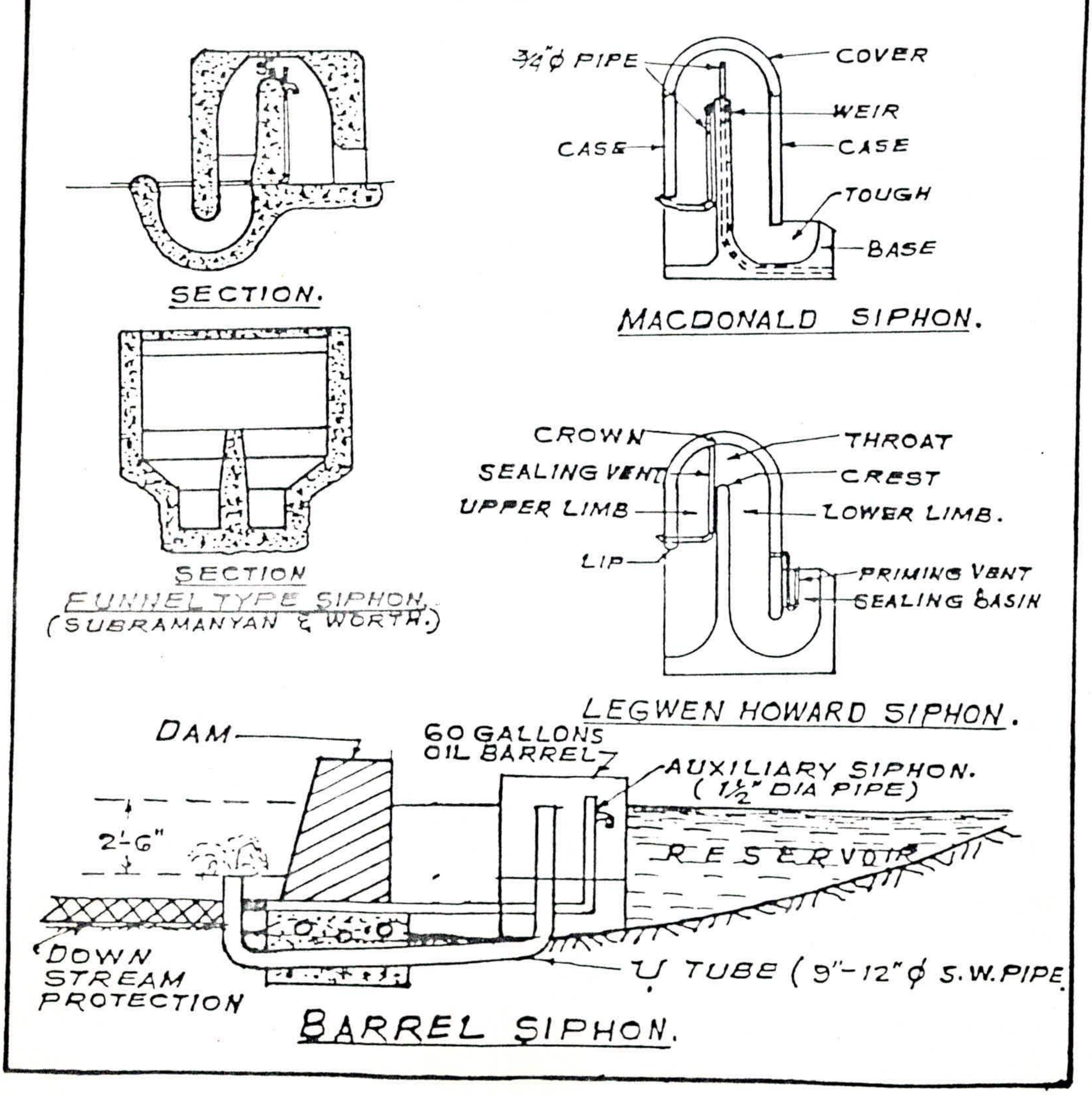
7. <u>Flushing</u>

For effective flushing a sufficiently large volume of water should be discharged suddenly at a minimum of once a week, or more often, with the object of causing a wave to pass down the channel or stream. This wave as it flows onward causes the stranding of mosquito larvae, pupae and eggs. Its effectiveness depends on a number of things: turbulence, splashing, stranding, the stirring up of silt, and the erosion of margins which is unfavourable for establishment of vegetation, algae etc. That serve as food or shelter to larvae. Many devices have been used including simple hand operated gates in dams, Jiggers used in Malaya, and carefully designed automatic symptoms, the latter appearing to offer one of the best types of water control.

Automatic Syphons

Devilliers, Macdonald, Williamson and Schraff, Worth and Subramanyan have originated and adopted syphons for sluicing in mosquito control. The designs of Macdonald, Legwen-Howard, and Subramanyan-Worth are shown in Fig. 2. They are basically similar in principle but differ in details.

FIG.-2.



The principle is to impound water by a low dam across the stream or river during the mosquito breeding season. When the impounded water reaches a predetermined level, the syphon discharges it rapidly as a flood wave that flushes a certain length down stream. The syphon discharge stops when the water level falls to a predetermined level. In Sri Lanka over thirty syphon dams were constructed during 1939-40 in rivers at widths ranging from 10' to 150' to control A.culicifacies. On experimental syphons Worth and Subramanyan determined the area of syphon required for different widths and slopes of stream in order to obtain an effective flushing length of approximately 5000' below the dam with a syphonic head ranging from 25 inches to 40 inches (as presented in the following table).

Area of syphon opening required in square feet for river flushing

Slope of stream	Width of stream in feet				
	30	60	80	100	150
1 in 50	1.41	2.82	3.76	4.70	7.05
1 in 100	2.01	4.02	5.36	6.67	10.05
1 in 200	2.82	5.64	7.52	9.43	14.14
1 in 400	3.99	7.98	10.64	13.33	20.00
1 in 600	4.89	9.78	13.04	16.33	24.50
1 in 800	5.64	11.28	15.04	18.88	28.32
1 in 1000	6.33	12.66	16.88	21.08	3.62

Source: Worth, H.N. and Subramanyan, K., Jr. of Mal. Inst. of India 3,1, June, 1940

Syphons may be precast or cast in-itu. A battery of syphons required for large rivers. They also can be installed on existing spillways of dams. Syphons must be designed to discharge sufficiently fast to give more than the velocity required to control the local mosquito species. This involves hydraulic consideration of head, width, slope, and roughness of stream. The length flushed depends on rate of discharge, the quantity of water stored above the syphon dam, and width and slope of stream. It also depends on inflow of stream at the moment. With dams 2-2 1/2' high length flushed is about 1500'.

With dams 4-4 1/2' high length flushed is 0.75 to 1 mile and the flush is stronger. Higher dams than these may cause submergence of adjacent lands, and perhaps may take more than a week to fill. Syphons dams can be built in the neighbourhood of towns and villages. Concrete is the most suited material of construction for syphons. But simpler devices can also be used like the barrel syphon shown in Fig. 2, for small streams and drains 6' to 20' wide.

In hilly country the syphon dam should be made strong enough to withstand the spate. At very low flows, the syphons will not work within a period of a week. For such situations a sluice should be provided which could be manually operated to flush once a week.

Jigger is another type of automatic flushing device designed and used in Malaya by Professor Williamson. It consists of wooden buckets placed into a low dam across the stream. The flow in the stream fills the buckets and tips and discharge into downstream. A counter-weight lever brings it back into an upright position for filling and emptying again. Rubber packings between the bucket and dam face are provided to prevent leakage between the bucket and the dam.

8. Other measures in Urban mosquito control

8.1 Besides construction of new drainage for effective prevention of water collections, existing drainage systems require proper modification, renovation, cleaning so that water or waste water is always kept flowing with a minimum velocity of 2' per sec to minimise mosquito breeding.

8.2 All appurtenences on existing sewerage systems should be kept in good working condition and in good repair.Gully pits are a potential source of breeding. They should be regularly cleaned of silt after every shower to prevent water stagnation in them. Similarly all auxiliaries of water distribution systems should be kept free of leakage.

8.3 Open storm drainage systems in country towns should be kept in good condition and regularly cleaned and oiled. To ensure adequate velocity of flow during dry weather, sections should be checked and remodelled with a semi-circular Cunnete for the invert for this purpose. Covering of all surface drains is preferred. Septic tank effluents should not be allowed into this system. Each septic tank should have its own subsurface disposal trench or soak pit.

8.4 All overhead and underground water storage tanks should be covered, and the ventillators should be checked for mosquito proof nets. Similarly all vent pipes provided in septic tanks and in on-site disposal latrines should be covered by mosquito proof netting.

8.5 Service latrines should be replaced by non-service type latrines.

8.6 Open drainage nallahs should be lined and channellised to ensure adequate velocity of flow throughout the season and cleared of marginal vegetation, floating debris, aquatic plants like water hyacinth, weeds, algae, and pistia which provide shade or abode for eggs, larvae and pupae. Installing flushing devices as discussed earlier may also be looked into.

8.7 All lowlying lands and marshy lands, abandoned wells and ponds should be either drained or filled as discussed in earlier paragraphs.

8.8 Swimming pools should be kept in a clean and unpolluted conditin. Top feeding minnows like Gambusia may be introduced in wells, ornamental tanks, water tanks for gardening, and other permanent pools. But they should be periodically checked for predators that may devour them.

8.9 Throwing of rubbish, garbage, discarded construction materials, cut branches of plants and trees etc. indiscriminately into city drainage systems is one of the major causes of water stagnation. This requires vigilance on the part of the civic authorities, and also an efficient solid waste management system. Education of the town people and their cooperation is essential for successful preventive health measure

8.10 Cattle sheds (khattals) inside the cities and towns are a source of mosquito and fly breeding. Civil authorities should strictly enforce laws to remove all these to outside the city limits.

8.11 Private premises should be inspected by mosquito control personnel at least weekly to identify and remove the small water collections described earlier.

8.12 Concrete floors in construction work may be cured by flushing once each week.

8.13 Health education of the public through mass media regularly will help to obtain the people's cooperation.

8.14 Developmental authorities for roads, railways and urban transit systems should consult civic authorities before laying of new roadways, railways or upgrading of existing roadway or railway embankments, in order to avoid interference with the natural drainage system of the town and to cooperate in making appropriate drainage plans and designs.

9. Maintenance

9.1 Efficient maintenance of all anti-mosquito engineering works is the keynote to the success of mosquito control by permanent engineering methods. Important maintenance aspects have already been discussed under different methods of control. In large cities and towns there is justification to have a separate department for maintenance of of drainage and other antimosquito works. The department should be headed by a P.H. Engineer trained in mosquito control works. Other technical and field staff of the department should receive inservice training in mosquito control measures. Drainage is the main problem of cities and towns. Regular cleaning of drains and their upkeep forms the major part of the work of these trained men. Besides maintenance of channels, important functions are the grading and sloping of embankments, and clearing of marginal vegetation, algae and water-hyacinth. Periodic inspection of houses to check water collections, vigilance to prevent creation of dumps obstructing drainage, and control of digging that might create pools, form a part of the work of this department. Periodic checking of public taps and standpipes, and their waste water disposal drains or soak-pits, and examination of ponds and swimming pools is essential to prevent creation of conditions favourable to breeding of mosquitoes. Inter-disciplinary co-ordination between the Departments of P.H., Roads and Railways, and Building and Irrigation is essential for proper maintenance of canals, roads, bridges and culverts, river and stream regimes, antimosquito drainage, storm drainage, tidal gates, flood control embankments, sluice gates, and automatic syphons etc., so that flooding and/or stagnant pools are not created and mosquito control measures are effective.

10. Summary and Conclusion

10.1 Most of the breeding places in urban and periurban areas are man-made and can be effectively eliminated by adopting suitable engineering methods.

10.2 Several methods of engineering control of mosquitoes are available, and choice of method for a particular situation should be carefully made by joint consultations between P.H. Engineers and malariologists. Suitability of methods is guided by the breeding habits of the local vectors and their ecology.

10.3 Different types of drainage for mosquito control may be employed, viz. surface, subsoil, vertical, contour, Fasine. Lido. Each of these methods have specific indications in urban mosquito control programmes.

10.4 Filling of all types of depressions has a special significance in urban mosquito control.

10.5 Training and channelization of small streams near towns is necessary if they are sluggish and have an intermittent flow.

10.6 Sluicing and flushing of streams and channels to destroy mosquito larvae and pupae can be adopted for small and medium size streams. Automatic syphons are best suited for this purpose.

10.7 Clearing of vegetation, removal of cattle sheds, removal of solid wastes, use of larvivorous fish in ornamental ponds and fountains, covering of all vent pipes with mosquito gauzes, periodic inspection of private premises for removal of small water water containers, are some of the special measures necessary for effective mosquito control in urban areas.

10.8 All categories of Engineeries, P.H. doctors and Sanitarians involved in mosquito control work should be adequately trained in engineering aspects of mosquito control operations. Both academic as well as practical training should be organised at several teaching institutions in collaboration with national institutes for malaria/ filaria control.

In conclusion, it may be said that with the resurgence of malaria and its particular problems of vector resistance to insecticides and parasite resistance to drugs, and in order to control filariasis, engineering methods of mosquito control are becoming increasingly important. These methods are sometimes expensive and may not always be feasible. They also require specially trained Engineers and Sanitarians. But to the extend funds permit, there is a strong case to revive these methods as supplements to the chemical and biological warfare against mosquitoes.

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HEALTH ASPECTS OF WATER RESOURCES PROJECTS

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1. INTRODUCTION

1.1 Vector borne diseases : In India the main mosquito borne diseases are Malaria, Filaria, Japanese encephalitis and Dengue. India is endemic for malaria except areas above 1500 m mean sea level and some coastal areas. In pre-control era - 1948, an estimated 75 million cases and 0.8 million deaths used to occur annually due to malaria alone in India. As a result of The National Malaria Control Programme (NMCP) launched in 1953 and later converted to National Malaria Eradication Programme(NMEP) in 1958 the malaria incidence was brought down to about 0.1 million by 1965. This was followed by malaria resurgence and the cases gradually increased to 6.4 million in 1976. Implementation of the modified plan of operation (MPO) since 1977 resulted in the decline of malaria cases to about 2 million. During 1988 NMEP reported 1.6 million cases of malaria, of which P. falciparum constituted 0.5 million (35%). There are nine vectors of malaria in the country. Anopheles stephensi is the vector of urban malaria which breeds in wells, overhead tanks, cisterns and rain water puddles etc. Almost all urban malaria in India is transmitted by A. stephensi. Anopheles culicifacies is the vector of rural malaria and peri-urban malaria. It is found in most parts of the country and has been incriminated from a large number of areas. The vector prefers to breed on ground and there is a sudden spurt in its populations with the onset of rains. It also breeds in a variety of other habitats such as wells, ponds, rice fields, irrigation channels, seepage water and marshy areas etc. Other vectors are of local importance such as A. balabacensis (dirus), A. philippinensis (nivipes), A. minimus, A. fluviatilis, A.varuna, A.annularis and A. sundaicus.

India is endemic for filaria and about 360 million people are exposed to the risk of its transmission. There are 18 million microfilaria carriers in the country and 8 million people with disease manifestation. Wuchereria bancrofti transmitted by Culex quinquefasciatus is the main vector followed by a small focus of Brugia malayi transmitted by Mansonia annulifera. The later infection is fast disappearing and getting replaced by W. bancrofti. The problem of filariasis is not fully delimited. Culex quinquefasciatus breeds profusely in polluted waters, and constitutes the bulk of mosquito populations responsible for high nuisance both in rural and urban areas.

Japanese encephalitis (JE) transmitted by Culex vishnui group of mosquitoes occurs in sporadic form. JE epidemics were first reported from 4 districts of West Bengal in July 1973. Thereafter JE epidemics are reported every year from West Bengal, Bihar, Uttar Pradesh, Maharashtra, Andhra Pradesh and Tamil Nadu. There is high morbidity and mortality associated with JE epidemics. The seasonal occurrence of JE coincides with spurt in Culex tritaeniorhynchus populations. The vector mainly breeds in rice fields, but also breeds in drains, ditches and fish ponds. The epidemics occur in rural populations that live in huts close to paddy fields and rear pigs.

Dengue is transmitted by Aedes aegypti which is a container breeder. It breeds profusely in urban areas in overhead tanks, cisterns, water stored in a variety of containers, desert coolers etc. Periodical dengue fever epidemics have been encountered in urban areas in the country.

1.2 Irrigation : India's irrigation potential before launching of the 5 year plans was 22.6 m ha. During the successive five year plans there was spectacular increase in irrigation in the country (see table 1). At the end of 6th plan (1980-85) 75 m ha would be under irrigation and the growth rate during the first 25 years was 1 m ha per year. During the subsequent years this growth rate has been stepped upto 2 m ha per year. The number of projects initiated (including spill over from the previous years) at the beginning of the 5th (1974), 6th (1980) and 7th (1985) plans were 75 major 155 medium, 176 major 447 medium, 240 major and 540 medium respectively. Seven hundred dams have been constructed and storage capacity is being increased from 160 thousand million cubic meters (mcm) to 234 thousand mcm (anonymous 1984).

TABLE 1 : CUMULATIVE POTENTIAL CREATED THROUGH MAJOR, MEDIUM AND MINOR IRRIGATION SCHEMES

	ACREAGE IN MILLION HECTARES		
DURATION	MAJOR	MINOR	TOTAL
Pre-plan period	9.7	12.9	22.6
Ist plan 1951-56	12.2	13.6	25.8
IInd plan 1956-61	14.3	15.8	30.1
IIIrd plan 1961-66	16.6	17.8	34.4
Annual plan 1966-69	18.1	22.3	40.4
IVth plan 1969-74	20.7	26.1	46.8
Vth plan 1974-78	24.8	28.8	53.6
Annual plan 1978-80	26.5	30.2	56.7
VIth plan 1980-85	31.0	-	-
VIIth plan 1985-90	37.5	-	-
VIIIth plan 1990-95	45.5	-	-
IXth plan 1995-2000	53.2	-	-
Xth plan 2000-2005	58.5	54.5	113.0

Source : Anonymous (1984)

2. IRRIGATION AND MALARIA

In certain parts of the country drought conditions may commonly persitst for 4-5 years, and the year 1987 witnessed one of the worst drought of this century. In the eastern region excessive floods periodically bring devastation. This drought-flood- drought syndrome has afflicted the country's over all development. Agriculture often receives a major set back due to uneven water availability in space and time, The high yielding varieties (HYV) and improved agricultural practices require an assured water supply, and therefore irrigation has always received major emphasis and has been rightly included in the 20-point programme of the Government of India.

Even before Sir Ronald Ross incriminated mosquitoes in the transmission of malaria, there was remarkable unanimity of opinion of the cause and effect relationship between irrigation and malaria. Russell (1938) has stated that " for example when Dempster in 1845 discovered the usefulness of the enlarged spleen in separating malarious from non-malarious communities, he was a member of a commission investigating unhealthiness associated with the western Jumna irrigation canal and stated "All our previous knowledge and experience would lead us to suspect some mischief from irrigating canals in such a climate as that of India, especially if not expressly constructed so as to preserve the drainage of the country and effectually to control the immoderate use of the water attributed the extreme prevalence of fever in many places which he visited to the rise of the spring level under the influence of canal irrigation". Another quotation from Macnamara concludes that a comparison of the statistics of towns in the irrigated and non-irrigated areas, that canal do excercise a direct influence upon the prevalence of fevers in the direction of their greater development and fatality. On irrigation Hehir (1927) wrote " Like many sanitarians of India, (the writer) knows that the heavy leakage from irrigation canals and channels is responsible for an enormous amount of endemic malaria". Covell and Bailey (1936) in reference to sind stated " We consider that maintenance of this high level of malaria incidence is largely attributable to conditions produced, directly or indirectly, by the operation of the Lloyd Barrage Scheme". And finally we quote Russell (1938) " Not only in India but in other countries this failure has been evidence, so that there exists the tragedy of engineer made irrigation malaria. Colossus stumbling over a gnat". In subsequent years relationship of irrigation schemes to the increasing incidence of vector borne disease incidence was well studied and documented.

In many areas of the country it was observed that opening of canals brought malaria to healthy areas. The commonly encountered reasons of irrigation malaria are the rise in sub-soil water resulting in water logging, poor drainage, minor engineering aberrations as leaky sluice gates, seeping canal banks, borrow pits, defective distribution chambers, improper delivery of water, poorly maintained canals, banks and beds, absence of sufficient number of bridges, general water untidiness, absence of controlled system of field channels, increased wet irrigation and lack of coordination between different agencies (Rao 1945, Rao and Nassiruddin, 1945).

Some studies have been reported from India on the relationship of dam construction and irrigation on malaria transmission. In north India irrigation has influenced the rise in ground water level in Haryana, Punjab and Westen Uttar Pradesh. As a result there are swamy conditions and poor water percolation during rainy season in large irrigated tracts. Breeding of A. culicifacies is commonly encountered in such areas resulting in high malaria transmission. Similarly Santhanaur reservoir and its vicinity in Tamil Nadu are responsible for half of rural malaria of the state of Tamil Nadu. It is also noteworthy to mention that heavy concentration of malaria is found in villages along the banks of the Pannaniyar river. A. culicifacies is the dominant vector which has found extensive breeding grounds as a result of the introduction of irrigition (Hyme and Ramesh, 1980).

Canal irrigation provides most favourable and extensive breeding grounds for mosquito proliferation. Sharma and Mehrotra (1982) pointed out that irrigation increases the average humidity of the atmosphere thus making the regions most conducive to mosquito survival. This produces a profound effect on the basic reproduction rate, thus enhancing transmission. Sharma and Uprety (1982) demonstrated that villages bordering canals had very high incidence of malaria whereas in villages with tube well irrigation the incidence of malaria was very low. Minor irrigation systems (tubes wells etc.) if properly maintained are less hazardous than the major and medium irrigation systems. As a rule mosquito problems are expected in the whole canal complex, the greatest risk being the minor distribution channels which are most suitable for mosquito production than the larger canals. The smaller the canal the greater is the chance for the mosquito multiplication (WHO, 1982).

3. IMPACT OF WRDPs ON OTHER VECTOR BORNE DISEASES

Besides malaria, WRDPs have also influenced the transmission of other vector borne diseases e.g. filariasis, JE and dengue. Clyde (1931) reported from Sarda canal head works that "It is remarkable that at the very beginning of the work *Culex* mosquitoes were practically non-existent but with the opening of the forest and construction of the camps a certain number began to appear. They never, however, became numerous, it being the exception to be able to catch 10 culicines for every 500 anophelines. The chief breeding places of these culicines were defective soakage pits and swamps contaminated with faeces". Recent studies by the Malaria Research Centre in the same area have shown that *Culex quinquefasciatus* populations have increased tremendously and as a result there is general mosquito nuisance in all semi-urban and urban areas. Added to this labour drawn from filaria endemic areas of eastern U.P. and Bihar regularly brings *Wuchereria bancrofti* infection and over the years, the area has become endemic for filaria.

There is an ever increasing demand of water in almost all urban areas which are expanding haphazardly without adequate sewerage and sanitation facilities. As a result water stagnates in open drains which have no outfalls or in the low lying areas. These are ideal breeding grounds for *Culex quinquefasciatus*. Kalra and Sharma (1987) reported that mosquitogenic potential is favourable for breeding of *Culex quinquefasciatus*, the pest mosquito in Delhi, generated under pressure of rapid urban growth has earned Delhi the nick name as "The city of Sullage Lakes".

There is acute shortage of water in most urban areas and as a result water is stored in overhead tanks, cisterns and other containers. *A. stephensi* the urban malaria vector and *Ae. aegypti* the vector of dengue breeds profusely in the stored water. As a result most urban areas of the country are endemic for malaria and dengue epidemics have been reported from several cities.

Irrigation has brought new areas under rice cultivation. Rice is the staple food in the country and wild flooding is one of the common irrigation practices. Irrigation has brought new areas under rice cultivation. Generally rice is rotated with non-rice crop. A recent development due to irrigation is that in many states like Karnataka, Tamil Nadu and Andhra Pradesh 2 or 3 crops of rice are taken annually thus providing extensive breeding grounds throughout the year. The practice of crop rotation i.e. rice followed by non-rice is beneficial in reducing mosquito breeding. Japanese encephalitis (JE) appears in sporadic or epidemic form mostly in rice growing areas of the country. Between 1950 to 1978 outbreaks of JE were reported from Tamil Nadu, Karnataka, Andhra Pradesh, West Bengal, Assam, Bihar, Uttar Pradesh, Pondicherry and Delhi. It is estimated that during 1978-83 there were 2367 deaths due to JE, out of a total of 7600 cases in India. The vectors are the members belonging to Cx. vishnui group, particularly Cx. tritaenioshnychus and Cx. vishnui and they principally breed in rice fields (Sharma 1986 a,b).

4. SECTORAL POLICIES AND DISEASE TRANSMISSION

Vector populations are regulated by a number of ecological factors. The interaction of various developmental programmes disturbs this ecological balance and may enhance, reduce or replace vector populations. Impact of sectoral policies on the vector borne disease situation in the country is described below.

4.1 Water Resource Development Projects - Irrigation: In the late 1940s cumulative irrigation potential in India was 22.6 mh. Since then she has harnessed her vast water resources and created an irrigation potential of about 68 mh. The irrigation targets have been set at 113.5 mh of which 58.5 mh is from major and medium schemes and 55 mh from minor irrigation schemes. In regard to health the National Water Policy (1987) states "Project planning for development of water resources should as far as possible, be for multiple benefits based on integrated and multi-disciplinary approach having regard to human and ecological aspects and special needs of disadvantaged sections of the society. Maintenance, modernization and safety of structures should be ensured through proper organizational arrangements." In practice health aspects of WRDPs are completely ignored. At present all major projects need clearance from the Department of Environment which unfortunately does not examine projects from the vector breeding view point. Breeding of insect vectors of disease takes place in seepage water and water logged areas, due to poor drainage and lack of proper maintenance. The planning commission (1985) has stated in the 7th five year plan document that existing irrigated areas where salinity and water logged areas have been identified adequate drainage facilities would be provided and it has become an important part of irrigation projects. It would be ensured that new project estimates would include necessary drainage arrangements. Lining of canal system either wholly or partially has been accepted as a necessary investment and it is being taken up on priority basis and importance of this approach has been accepted by the States. In Punjab, Haryana and a few other states lining of substantial stretches of canal has already been completed. It may be mentioned that lining of canals is being done to prevent water loss and not for any health consideration, such as the prevention of mosquito breeding. In fact there is no awareness of this aspect of environmental degradation among the planners and engineers. The grassy margins all along the canal and its tributaries provide ideal breeding places for mosquitoes. To irrigate command areas water in the canal is released on rotation basis. This policy has been adopted on the recommendation of the World Bank policy of equitable distribution of water. Water is released at 4 to 6 weeks interval. During the period when regular flow in the canal is closed a thin sheet of standing water supports heavy mosquito breeding, an ideal site for proliferation of A. culicifacies, the control of which is most difficult. A weekly release of water would ensure control of mosquito breeding by flushing effect but this is never done.

It is notable to mention that the scheme on Sarda Canal project (Banbasa, U.P) was sanctioned in 1913 to irrigate 12 famine prone districts of Oudh. The work could not be taken up immediately due to World War I and also the fact that the requirement of the number of the drainage outlets to prevent water logging in the command area could not be ascertained. This was considered essential because following the opening of Ganga Canal in 1854 there was a rise in sub-soil water and water logging which resulted in an increased incidence of malaria. It is noteworthy to mention that drainage in command area was ensured before the opening of Sarda canal in 1929. Malaria Control by spraying residual insecticides changed the outlook of planners and this aspect of drainage did not receive adequate attention. Jayaraman (1982) clearly brings out the importance of drainage from the command area of Mahi-Kadana project in Kheda, Gujarat. In this area year round irrigation and multiple cropping of paddy has resulted in an increase of malaria over an 18 year period. The situation is worsened by over-irrigation and poor drainage.

A better water management system and continuous monitoring of the projects by an inter-disciplinary team comprising of a public health administrator would be the logical solution to the problem rather than insecticide spraying which at present does not produce the desired impact. Irrigation brings prosperity by increasing agricultural production. Labour is imported for various developmental and agricultural works. The labour force brings infection from malaria endemic areas and settle along the water courses. In all such areas malaria incidence increases manifolds. Wherever canal irrigation is being encouraged the first disease to get a strong foot hold is malaria. A study in Haryana by Sharma and Uprety (1982) showed that villages with canal irrigation had high malaria but those with tube well irrigation were free from the disease. Therefore irrigation departments must ensure that canals are maintained properly so as to prevent water stagnation either in the irrigation system or in agricultural fields. This neccessitates increased modernization, knowledge of adverse health impact, monitoring, maintenance and provision of adequate funds. Even at the present time no efforts are being made to study the cause and effect relationship of vector borne diseases in the irrigation systems.

As a follow up of in-depth evaluation (1985) report of NMEP, the Ministry of Health and Family Welfare approached various ministries and departments concerned for creating an inbuilt infrastructure to combat malaria. Comments have been received from the Ministry of Agriculture (deptt. of rural department) and Central Water Commission (systems engineering). They have given the following suggestions to the Ministry of Health.

(i) Standing Committee (Advisory) may be constituted at national and state levels to regulate the developmental projects/ activities under the chairmanship of respective health secretaries. Members may be drawn from departments like rural development, water resources, irrigation, public health engineering, urban development, agriculture and industries.

(ii) As malaria is very much connected with water engineering and water development projects, there is a necessity to train engineers of concerned departments.

4.2 Agriculture : A study at the MRC showed poor relationship of rice cultivation with malaria (Sharma 1987). Studies also showed that A. culicifacies breeds in rice fields throughout the plains of India although its proportion varies from place to place. The vector prefers sunlight and therefore breeding is encountered in fallow fields and rice fields upto 6-8 weeks and breeding terminates when the plants attain a height of about 20 cms. The second vector A. fluviatilis breeds in channels of rice fields although breeding is scanty but occurs in some areas almost throughout the rice cultivation season. With the coming of canal irrigation, two crops and at many places in southern India even 3 crops in a year have become common, thus the period of standing water in the fields has extended for a very long time thus allowing continuous breeding of malaria vectors. Culex quinquefasciatus the vector of filariasis also breeds in rice fields. Besides Culex vishnui group of mosquitoes breed profusely in the rice fields (Sharma 1986, 1987). In recent years outbreaks of J.E. have become very common.

Population movement for agriculture is spreading the disease. An example may be cited of U.P. terai which is the green belt of U.P. In this area before the control programme was launched Culex quinquefasciatus populations were negligible. With the urbanization and poor drainage C. quinquefasciatus mosquito populations have increased enormously. Labour for agriculture is imported from eastern U.P. and Bihar where the incidence of filariasis is very high. In the last decade or so the terai area has also become endemic for filariasis. Besides vast areas are under rice cultivation, and Culex vishnui mosquitoes breed in these rice fields making the area prone to JE epidemics (Sharma 1986). At present there is no policy to check population movement or migration and this is resulting in the dissemination of vector borne diseases e.g. malaria and filaria to areas free from the disease. Plasmodium falciparum containment programme (PfCP) has introduced a system of providing radical treatment to itinerent labour moving into or going out of north eastern region of the country and this policy helped in the containment of drug resistant strains of Pf to other areas (A.P. Ray personal communication).

4.3 Urban Malaria : WRDPs supply water to urban areas. In most urban areas water supply is not properly maintained resulting in leakage of water pipes. Similarly water storage results in mosquito breeding. In most towns drainage system is not installed. Stagnation of water allows breeding of a variety of mosquitoes. Besides irrigation in peri-urban areas also provides opportunities for mosquitoes to breed. As a result malaria is a serious problem in urban areas accounting for about 15-20% of all cases of malaria in the country. In 1971-72 Govt of India (GOI) sanctioned urban malaria scheme (UMS) in 133 towns distributed in 17 states and 2 union territories (NMEP, 1986). The scheme was implemented in a phased manner. Criteria for the selection of town under the UMS were :

(i) The population of the town should be >40,000.

(ii) The Slide Positivity Rate (SPR) and Annual Parasite Incidence (API) each should be 2 or more provided Annual Blood Examination Rate (ABER) is atleast 10%, and

(iii) Local bodies should have bye-laws directed towards vector control or should give an undertaking that they will adopt and implement bye-laws within two years.

UMS is in operation in 127 towns. GOI accorded sanction for 10 new towns during 1988-89 and another 38 towns are likely to be accorded sanction during 1989-90. There are 203 towns covered under National Filaria Control Programme (NFCP). Except in Kerala, Karnataka and Bihar, most of the towns under NFCP are endemic for malaria. The towns in UP, Bihar, Andhra Pradesh, Karnataka and West Bengal are also prone to dengue and JE epidemics (UMS 1986) The following decisions are being implemented.

(i) In urban areas separate programmes for vector borne diseases like malaria, filaria etc are being amalgamated in to one programme of vector borne disease control. Such a programme is already in existence in Chandigarh (UT).

(ii) Building construction projects are progressing at a fast pace in urban areas. In these cities A. stephensi breeding sites are being created resulting in focal outbreaks. Therefore it is suggested that construction project authorities should deposit 1% of the total cost of construction work as health charges.

(iii) Bye-laws to prevent vector breeding are being enacted or extended to urban areas.

It is very early to predict the outcome of these measures on the containment of vector breeding.

The world commission on environment and development observed that "out of India's 3119 towns and cities, only 209 had partial and only 8 had full sewage and sewage treatment facilities" (Our common future, 1987). As a result breeding of Culex mosquitoes in all urban areas of India is intense and the situation is hapless.

Although bye-laws have been enacted in most urban areas to prevent mosquito breeding but in practice these bye-laws are seldom used, the only exception is Bombay. Table 2 provides data of malaria incidence in 4 metropolitan cities of India. Of the four cities the programme of Bombay municipal corporation is extremely well executed with the help of legislative measures, and malaria is under control. But a new township is coming up in Thane district, about 20 Km south-east of Bombay named New Bombay. Development of this area has been taken up to remove congestion from Bombay. The area is under Panchayat (village council) and there were no legislative measures to control malaria. As a result innumerable A.

stephensi and A. culicifacies breeding sites were created and there was persistent malaria transmission and occasional outbreaks. However, recently Bombay bye-laws have been extended to this city and since then the malaria incidence has declined.

In Calcutta malaria cases are increasing at an alarming pace. The breeding of A. stephensi increased enormously due to potential created by the construction of metro-rail. A notable feature of mosquito breeding sites was that large borrow pits created due to metro-rail work were not filled up due to fear of unauthorised occupation of land. Stagnant water in the borrow pits supported heavy mosquito breeding. Besides Greater Calcutta has a population of 10 million but malaria or mosquito control programme is in existence in Calcutta town only which has a population of 3.5 million. In the remaining 6.5 million population although there are 38 municipalities but there is no malaria control programme.

Madras city contributes 55-60% malaria cases of the state of Tamil Nadu and 70% of all cases come from urban areas. The vector is A. stephensi which breeds in wells, overhead tanks, cisterns etc., although legislative measures can be of great help in reducing vector breeding but these are seldom used. Most overhead tanks are not mosquito proof. Further they are inaccessible, and what is worse even today such faulty overhead tanks are under construction.

Delhi is endemic for malaria and although bye-laws exist these are too weak and not implemented. In Delhi there are several agencies which are responsible for malaria control in their own areas such as the All India Radio, Zoological Gardens, Jawahar Lal Nehru University, Indian Institute of Technology, Municipal Corporation of Delhi, New Delhi Municipal Corporation etc. Most of these institutions lack funds and adequate trained man power with skills to control vector breeding. Besides several agencies involved in development of Delhi do not coordinate in any meaningful manner. As a result sudden spurt of vector population and malaria epidemics are common. Besides Delhi is visited by dengue epidemics at periodical intervals. Uprety et al (1983) reports that on an average 22.3% (range 7.4 to 52%) overhead tanks were breeding Aedes aegypti.

TABLE 2 : MALARIA CASES IN FOUR METROPOLITAN CITIES OF INDIA

S.NO.	CITIES	POPULATION (IN LAKHS)	NO. OF MALARIA CASES				
			1984	1985	1986	1987	1988
1.	Bombay	82.27	2610	1371	833	1864	4073
2.	Delhi	75.19	38108	23495	23749	24455	14423
3.	Calcutta	91.65	26056	18001	15723	8285	16465
4.	Madras	32.66	48523	51376	39197	30771	35459

5. POLICY ISSUES FOR CONSIDERATION

Vector breeding could be mitigated to a very large extent if inter alia some crucial issues discussed below are addressed adequately.

5.1 Inter-sectoral Collaboration: This is the most important issue which is generally ignored, partly because at times eliciting intersectoral collaboration is rather difficult. It should be adopted as a policy and all programmes should be coordinated at the Centre and district level from the very beginning to contain vector breeding.

5.2 Legislation: There are bye-laws to govern and regulate the economy and protect the environment and human health viz., Environment (Protection) Act, 1986, Factories Act, 1948, Northern Indian Canal and Drainage act, 1873, Water Policy of India, 1987, Andhra Pradesh Public Health Act, 1945, Tamil Nadu Public Health Act, 1939, Bombay Municipal Corporation Act, 1988, The Goa, Daman and Diu Public Health Act, 1985, and Goa Public Health rules, 1987. Similar acts and bye-laws have been instituted in most states/UTs. Keeping in view the background of vector borne diseases and the importance of their containment, existing bye-laws may be reviewed and those found weak should be amended and made more stringent. Enforcement of bye-laws should receive utmost priority.

5.3 Water Management: Water resource development projects (WRDPs) constitute an important vector breeding sources. While it is appreciated that building of sound economy depends on harnessing water but this very resource of prosperity should not produce health hazards. In all WRDPs preventive rather than curative aspects of health should be in-built. Technologies are available to safeguard health but these are seldom applied. Wherever possible lining of canal is a good solution to vector breeding, although initial investments are high. The cost of lining is recovered in about 4 years by savings on water. Irrigation as it exists today is in a chaotic state with problems of uncertainty and irregularity in distribution. This leads to over irrigation and water logging. In many areas rotational water supply (RWS) has been introduced and the outlet command area is irrigated at fortnightly or monthly intervals. Standing water in the canal results in profuse vector breeding. Therefore weekly irrigation or flushing should be adopted as a policy to control vector breeding. Importance of drainage in irrigation projects should not be lost sight of, as is the case most often. In such areas vector breeding assumes menacing proportions. Besides a certain amount of funds should be earmarked for the maintenance works in the WRDPs and command area. The irrigation system consisting of branches, minor and sub-minors should be properly graded, maintained and cleaned of weeds to prevent vector breeding. It may be emphasized that health departments should be responsible to monitor health related aspects of irrigation and corredtive measures suggested by them should be mandatory.

5.4 Rural and Urban Water Supply: should be contingent on the sound drainage system for spent water Regular Maintenance of both systems should be ensured.

5.5 Standard Designs, Prototypes etc.: It would help to develop standard design/prototypes for water storage tanks, sumps building designs of certain structures, fixtures etc. Only those designs that have the approval of the Govt. should be permitted to be installed/constructed and this may be enforced by an act.

5.6 Labour Migration/Settlements : Labour movement from endemic areas to non-endemic areas or labour returning home may disseminate infection of parasitic diseases. It is necessary that itinerant labour is well protected by administering radical treatment on arrival and departure. Besides it should be ensured that the labour is sited in healthy camps, away from vector breeding sources with proper water supply and drainage. This should become part of the contractual agreement and any violation should attract penal action.

5.7 Fisheries : Inland fisheries are encouraged through the fisheries department cooperative societies and private parties. In many areas fish culture is not done on scientific lines and ponds are not well maintained. if should be made mandatory for the inland fisheries department or private enterprenuers to ensure that margins of ponds are deepend and deweeded periodically. Fish culture should also include production of larvivorous fishes such as guppy or gambusia which are compatible with carps etc.

5.8 Agriculture : There are various examples of ecological succession of vectors and biological invasion of insect vectors of diseases. This may be the result of ecological disturbance such as deforestation, aforestation, digging of borrowpits, mining activities, change in salinity, irrigation etc. This often results in the replacement of one vector species by another or the introduction of new vectors in the area. In order to prevent such a possibility it should be mandatory to evaluate health risks beforehand and corrective measures incorporated in the plan.

6. CONCLUDING REMARKS

There are no systematic studies in the country from the time WRDPs are constructed on the breeding potential of different vectors of diseases and consequent disease transmission. However some observations have been made on the status of malaria or filaria and how they became endemic after the WRDPs were created. There are a variety of factors that promote the vector borne diseases from the time WRDPs are conceived upto the end use. Some of these are the congregation of labour living under unhygienic conditions, population displacement, creation of borrow pits, seepage, submergence of large tracts of agricultural land, fishing improved agriculture as a result of opening up of canals etc., migration of population from endemic areas particularly during the harvesting season, etc. All these factors profoundly effect the pattern of disease transmission. A systematic study is required on the impact of WRDPs on the mosquito breeding and vector borne disease transmission. It is important that corrective measures are incorporated during the construction phase of the project itself and implemented meticulously. Unfortunately at present 2 or 3% project money meant for malaria control is being utilized in curative such as opening of dispensaries etc. rather preventive health services This lecunae has been pointed out at several forums and more recently by the international group of experts during the in-depth evaluation of the Modified Plan of Operation under the National Malaria Eradication Programme held in 1985 and I quote "Project induced malaria has been a major problem. With the developmental activities gaining momentum under the 5 year plans, malaria in developmental projects has been on the increase. Power irrigation and industry are the core sectors receiving highest priority in developmental plans. In project congregation of labour drawn from different parts of the country living in adverse conditions, as well as in mosquitogenic conditions created by water logging/poor water management, provides ideal conditions for malaria transmission. There are innumerable examples of irrigation projects where malaria was rampant during the construction phase of the dam as well as its canal systems. Often even the maintenance phase of these irrigation projects, malaria continues to be a problem because of improper designing or failure in providing drainage facilities as well as imperfect/ bad water management. The committee while discussing with the Central Water Commission was informed that it has prepared elaborate guidelines for the irrigation projects which includes provision for anti-malaria and health measures. Neverthless, the states, who are usually the implementing authorities of the major and minor irrigation projects, failed to implement adequately the anti-malaria and health measures. Often they are satisfied in providing only a dispensary with a medical officer for giving curative services. Preventive aspects are totally neglected. Many times it is left to the health department of the state for providing these facilities with their meagre resources". Above statement summarises the totality of picture of the WRDPs and how they are affecting the transmission of vector borne diseases in India.

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Water Resources Development Policies, Environmental Management and Human Health

R. Bos

The international discussion on environment and development sparked off by the Brundtland report[1] has resulted in a renewed focus on how development policies are often at the roots of environmental degradation and of a subsequent deterioration of human health status. In this context, the WHO/FAO/UNEP Panel of Experts on Environmental Management for Vector Control (PEEM) at its ninth meeting (Geneva, 11–15 September 1989) discussed policy issues as they relate to the vector-borne disease implications of water resources development projects[2].

In principle, two types of policies can be distinguished: government policies, at the national planning level as well as in the sectors responsible for water resources development, which may inadvertently have repercussions for the health status of population groups involved, and donor and development agency policies, which essentially deal with criteria and conditions for development assistance. Policies of the latter category were discussed by type of agency, ie. bilateral agencies, multilateral United Nations (UN) agencies and multilateral development banks and funds.

As can be expected, a review of government policies resulted in a wide range of issues, even with the rather limited sample of countries discussed. In Egypt, where the link between irrigated agriculture and schistosomiasis has long been recognized, the government's food policies (pricing of agricultural produce, food subsidies and compulsory cropping patterns) have left the agricultural sector with little surplus for private investment. Insufficient investment in system maintenance has no doubt contributed to the creation of situations favourable to the propagation of the snail intermediate host. In India, the water resource sector traditionally took into account health aspects and this was reflected in its policies. In the 1930s, for instance, the Sarda Canal Project did not become operational until proper drainage was ensured. The objective of policies to provide drainage for all irrigation schemes was primarily to prevent water-logging-induced mosquito vector breeding. Such policies were abandoned following the introduction of residual insecticides for vector control. Current policies in India that have an alleged adverse effect on malaria transmission include the policy of rotational water release, which aims to achieve a more equitable distribution of irrigation water. This system leaves pools of water in the empty canals during the irrigation intervals, in which vector breeding occurs. Policies aimed at livestock promotion may have a detrimental effect on human health if the domestic animals play a key role in the epidemiology of a disease eg. pigs in the case of Japanese encephalitis. The mechanics of the latter example have been described in detail elsewhere[3,4].

In some countries, policies aimed at ensuring the incorporation of health safeguards into irrigation projects have been formulated. These address either the decision-making processes at the planning and design stage of a project, or the establishment of effective institutional arrangements between sectors involved. Examples were quoted from the Philippines, where a number of memoranda-of-understanding regulate the collaboration between the health, irrigation and public works sectors[5], and from Ethiopia, where an initiative (the Committee for Inter-institutional Collaboration) has developed on an informal basis. The experience in Thailand shows that legal requirements for environmental impact assessment are not always a guarantee that human health impact assessment is covered adequately. The dichotomy between health and environmental issues was observed in other aspects as well.

Policies should never be considered as definitive; as national and regional priorities shift they may have to be reconsidered and adjusted. In the Tennessee Valley of the USA, policies to gear the design and operation of the Tennessee Valley Authority's (TVA) big reservoirs towards mosquito vector control have been the basis for the successful elimination of malaria. Priorities have now shifted to recreational reservoir uses but the fluctuations in water level, aimed at controlling vector breeding, interfere with these recreational goals. Also, growing environmental concern with respect to wetlands has made protectionist policies clash with vector control policies. It is clear that in the present-day reality, certain TVA [illegible] may need adjustment, but the [illegible] of reversing the successful achievements of existing policies by doing so need [illegible] properly weighed.

It was concluded that, almost without exception, countries have experienced problems in establishing effective inter-sector collaboration aimed at [illegible] environmental management measures in development projects. Although [illegible] developing countries have introduced procedures for environmental impact assessment, their application has been constrained by institutional and administrative deficiencies, lack of trained staff, political manipulation or lack of funds.

Bilateral assistance agencies direct their efforts towards relief of poverty, the sustainable development of natural resources and protection of the environment. They provide official development assistance in the form of loans and grants, with a major element being technical assistance. Most agencies have, in the last couple of years, embraced the concept of sustainable development, but in their programmes they still have to find the mechanisms to bring this into practice. The inherent long-term character of sustainable development, with its requirements for monitoring, reviewing and evaluating, conflicts with the usually limited periods of donor support. The same intersectoral gaps found at the national level in most developing countries are also apparent in the structure of most bilateral agencies. Health sector specialists are involved in assistance programmes aimed at strengthening health services in recipient countries, but are seldom involved in the assessment of proposals for resource development projects for their human health dimension. It was also noted that many bilateral agencies, in an attempt to visibly maximize the benefits of their aid funds to developing countries, decentralize staff and expenditures. This trend, together with the rapid turn-over of desk officers, adversely affects the corporate memory of the agencies in the complex matters of environment and health during resource development projects.

In the multilateral arena, the various UN programmes and specialized agencies have all responded to the request by the UN General Assembly to review their policies and programmes in the light of the Brundtland Report's recommendations. This has resulted in a plethora of position papers, policy statements and resolutions of the various governing bodies. These respond mainly to the pressures of the conservationist lobby, and they have yet to evolve to include a more comprehensive concern for the human dimension, in particular human health. Thus the peculiar dichotomy between environment and health already mentioned is again observed. The most promising trend in the multilateral agencies' programmes is the increased emphasis on monitoring and evaluating the effects of development on the environment and on human health. The UN system, with its broadly based programmes and continuous presence in the member states, seems to be most suited to help countries in developing the human resources needed for this task.

Multilateral development banks and funds are in a special position to promote consideration of human health in development projects. Leaving aside the possibility of including health as a component of an overall environmental package to be negotiated at the appraisal phase of a project (eco-conditionality of loans is a sensitive issue for most developing countries), there is ample scope to include health status guarantees in the project design. In the case of potential vector-borne disease impact, environmental management measures included in the design should be complemented by a strengthening of health services adequate to meet the needs of the new circumstances. If a recipient government is reluctant to accept the health component as part of the loan, a grant for technical assistance in this area from a bilateral or multilateral agency could be the solution.

The World Bank has taken the lead in donor policy formulation by introducing procedures that treat the environment as part of a country's normal economic and sector work. This will involve the preparation of briefs outlining the principal environmental issues of each country. However, it is not clear to what extent human health will be specifically considered in the framework of these procedures.

In the World Health Organization, interest in this area is growing steadily. The endeavour by the WHO/FAO/UNEP PEEM is only one example. As a major initiative, WHO has established a high-level commission on health and environment, which will assess the health consequences of the environmental and development crises. The conclusions and recommendations of the commission will constitute WHO's substantial input into the 1992 UN conference on environment and development. In another initiative, WHO and the World Bank are collaborating in studies on the impact of economic adjustment and development policies on human health status. A broad literature review is ready for publication.

The analysis carried out for the 9th PEEM meeting has been published as document VBC/89.7 (Policies and Programmes of Governments, Bilateral and Multilateral Agencies and Development Banks for Environmental Management in the Context of Natural Resources, Agriculture and Health Development)[2] and is available from the PEEM Secretariat, WHO 1211 Geneva-27, Switzerland. The panel's discussion, conclusions and recommendations will be included in the report of the 9th PEEM meeting, to be published in May 1990 as document VBC/89.1.

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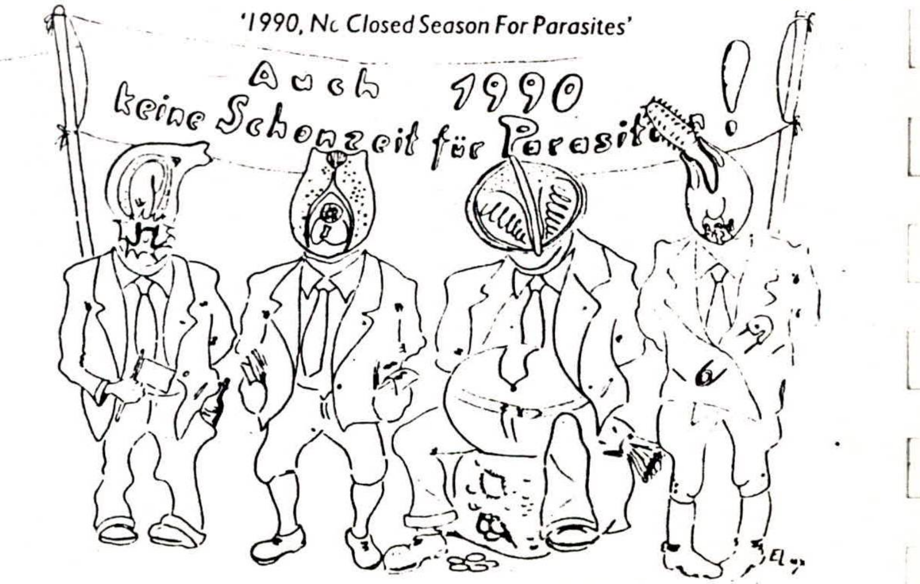
'1990, No Closed Season For Parasites'



(Cartoon by Ekkehart Lux of the Akademie der Wissenschaften der DDR, Am Tierpark 125, 1136 Berlin, DDR.)

Malaria Control by Engineering Measures: Pre-World-War-II Examples from Indonesia

W.B. Snellen

Malaria Control by Engineering Measures: Pre-World-War-II Examples from Indonesia

W.B. Snellen

Malaria

Malaria is among the oldest recorded diseases. There are references to its intermittent fevers in Assyrian, Chinese, and Indian texts that date from many years before Christ. An ancient Chinese text, for instance, described the three malaria demons: one with a hammer, one with a pail of cold water, and the third with a stove, representing the symptoms of the disease: headache, chill, and fever.

Around 400 B.C. in Greece, Hippocrates, who is traditionally considered the father of western medicine, reported on intermittent fevers, writing that residents of low, moist, and hot districts who drank the stagnant marsh water suffered from enlarged spleens. (Malaria leads to an enlargement of the spleen.)

In ancient Rome, around the year 100 A.D., Columnella, in *De Re Rustica* (Rural Matters), suggested the inadvisability of building a house near a marsh because '[the marsh] always throws up noxious and poisonous steams during the heats, and breeds animals armed with mischievous stings, which fly upon us in exceedingly thick swarms ..... whereby hidden diseases are often contracted, the causes of which even the physicians themselves cannot thoroughly understand' (Russell et al. 1946).

Columnella was quite right. It took physicians another eighteen hundred years to discover that malaria was transmitted by mosquitoes. In 1880, in Algeria, the French army surgeon, Laveran, discovered and described malaria parasites in human blood. Even then, it took another twenty years before the mosquito-malaria transmission theory could be confirmed through the research of another army surgeon, Ronald Ross, who received a knighthood and the Nobel prize for his work.

The Romans didn't need Ross's discovery. They had already traced intermittent fevers back to poisonous airs from swampy terrain and called the disease *mal'aria* (bad air). The association of fevers with stagnant water and swamps led the Greeks and Romans to practise various methods of drainage from the sixth century B.C. onwards. Drainage to improve health conditions continued throughout the Middle Ages in Italy, Spain, France, Holland, England, and elsewhere.

In the U.S.A., the transactions of the American Medical Association of 1874 were largely devoted to a symposium on drainage as related to public health, especially to the malaria fevers. But it was only after 1900 and Ross's discovery of the mosquito transmission that malaria control got a proper scientific base.

Basic Control Strategies

The greatest early-twentieth-century demonstration of what can be achieved with malaria-control measures was furnished by William Crawford Gorgas, an American army

surgeon working in Panama. A French engineering company had been trying to build the Panama Canal from 1881 to 1889. They failed because of enormous human and financial losses due to malaria and yellow fever. In eight years, the French had lost two hundred million dollars and five thousand lives. The Americans bought out the French firm and started working on the canal in 1904, completing it in 1914.
Gorgas used three basic strategies:
- Medical treatment: every worker who got malaria was given quinine immediately and had to line up each day for the next six weeks to take his pill;
- Reduction of vector-human contact: houses were screened; field construction workers had to live in tents or railroad cars that were fitted with mosquito screens;
- Reduction of vectors: Gorgas's men drained swamps and other breeding places if they could; if they couldn't, they treated surface water with a locally-developed larvicide.

In ten years, Gorgas spent three million dollars to control malaria, with the following results:
- Sickness among the work force dropped from 800 per 1,000 workers in 1904 to 40 per 1,000 in 1914;
- Death from disease in the same period dropped from 40 per 1,000 to 8.7 per 1,000.

It is estimated that Gorgas saved the U.S. some forty million man-days of sickness and some seventy-one thousand deaths in the ten years of canal construction. President Roosevelt promoted Gorgas from the rank of major to general; Oxford University gave him an honorary Doctor of Science degree, and King George V of England made him a knight [and shortly afterwards gave him a state funeral] (Russell et al. 1946).

Gorgas ran his malaria-control effort in Panama very much like a military operation. This was possible because he protected a work force that had to follow his orders and whose living conditions he could control. Of course, in a free society, you can't force people to take pills if they don't want to. And if people live in huts made of bamboo, there isn't much point in screening the windows.

Because of the difficulty of implementing the first two strategies, the malaria-control efforts in many countries at that time relied heavily on the third strategy: vector control. And because there was no effective insecticide like DDT, the most important vector-control measures were those aimed at eliminating or modifying breeding sites.

The importance of drainage and water management can be seen in the publications on malaria control of that period:
- The manual, *The Engineer and the Prevention of Malaria*, by Henry Home, published in 1926; it contains no less than four chapters on drainage;
- *Practical Malariology*, a medical book produced in 1946 by Russell et al. for the U.S. National Research Council; it devotes a whole chapter to 'Drainage and Filling' and describes many more water-management practices in other chapters.

The DDT Era

But in the handbooks on malaria control that appeared after 1950, there was no reference to drainage or other engineering measures. When DDT became available, the practice of eliminating or modifying breeding sites and reducing man-vector contact -- both by environmental management measures -- was replaced by a single method: spraying the walls of houses in malarious areas with two grams of DDT per square metre.

Initially, this method produced very impressive results. So, in 1957, the World Health Organization (WHO) set up a worldwide programme of malaria eradication. India and Sri Lanka provided good examples of what could be achieved. The number of cases in India dropped from seventy-five million in 1951 to fifty thousand in 1961. Sri Lanka, with three million cases in 1947, had only twenty-nine in 1964. But just a few years later, the malaria cases were being counted in hundreds of thousands (Harrison 1978).

The programme failed because some of the species of malaria mosquitoes had developed resistance to insecticides: they could now tolerate doses that were sure to have killed previous generations of the same species. By 1980, of the one-hundred-and-seven countries where malaria occurs, mosquito resistance to insecticide had been reported in sixty-two of them. This meant that it was no longer possible to rely on the chemical control of malaria mosquitoes. In fact, we are now back in the situation that existed before World War II: not being able to rely on chemical control, we have to return to an integrated approach and use all available methods.

ILRI and PEEM

In 1981, in recognition of the above, WHO, FAO, and UNEP established the joint Panel of Experts on Environmental Management for vector control (PEEM). By bringing together organizations and institutions involved in health, water and land development, and the protection of the environment, PEEM is promoting the use of environmental-management measures in development projects.

The role of irrigation and drainage engineers in the control of malaria and other vector-borne diseases is reflected in the technical publications produced through PEEM:
- *Environmental Management for Vector Control in Rice Fields.* FAO Irrigation and Drainage Paper 41;
- *Proceedings of the Workshop on Irrigation and Vector-Borne Disease Transmission.* International Irrigation Management Institute;
- *Guidelines for Forecasting the Vector-Borne Implications in the Development of a Water Resources Project. (Draft Version).*
- *Manual on Environmental Management for Mosquito Control.* WHO Offset Publication 66.

(PEEM also issues a quarterly Newsletter in English, French, and Spanish which can be obtained free of charge from the PEEM Secretariat, World Health Organization, 1211 Geneva 27, Switzerland.)

In 1984, ILRI established the 'Health and Irrigation Group', and later that year became a Collaborating Centre of PEEM. The Group has been working on the forthcoming ILRI publication *Irrigation and Health*, by Ir J.de Wolf and Dr J.M.V. Oomen. The purpose of this publication is to create an awareness among development workers and policy-makers that irrigation development involves the risk of introducing or spreading vector-borne diseases, and that preventive measures can be incorporated into the design and operational procedures of irrigation projects.

Indonesian Experiences

As part of its collaboration with PEEM, ILRI is collecting and reviewing literature on malaria control under the colonial administration of the Dutch East Indies prior to 1940 – with special emphasis on measures related to land and water development. This Indonesian experience is providing valuable information on the approach, organization, implementation, and effectiveness of environmental methods for malaria control. This information has largely been forgotten, owing to the discovery and large-scale application of DDT and also because almost all the original material had been published in Dutch.

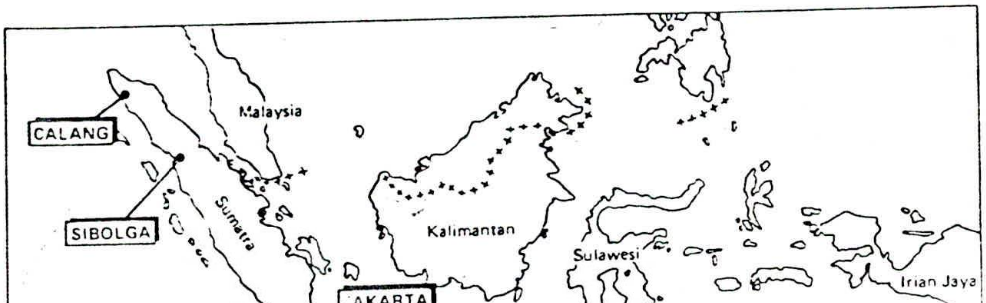


Figure 1. Location of case studies

Early Sanitations: Sibolga

One of the earliest sanitations i.e. malaria control by technical measures – took place in Sibolga from 1913 to 1919. Sibolga was the administrative and trade centre of the regency Tapanoeli on the West coast of Sumatra (Figure 1). Sibolga had always been an unhealthy place. In 1912, the health situation had deteriorated to the point where every household – European and native alike – was afflicted with malaria. A Government doctor who was sent to investigate the malaria problem reported a mortality rate for the year 1912 of 79.5 per 1,000 and a spleen index of 98. [The spleen index is the number of enlarged spleens found in 100 examined persons.]

Table 1 indicates the breeding sites of Anopheline mosquitoes and the measures that were taken to eliminate them.

Table 1. (Source: Nieuwenhuis 1919)

Location	Breeding sites	Control measures
Coastal swamp	Depressions at the edge of the swamp, above the normal high-tide level. They are reached by seawater only at spring tide and, after dilution with rain water, create stagnant pools of brackish water	Edge of the swamp filled up above spring-tide level; grading and levelling; construction of stone-lined embankment
Town (seaside)	Stagnant rainwater in depressions, due to poor drainage (high watertable and low soil permeability)	Filling in depressions and raising surface level to 0.15 m above spring-tide level; surface grading 1:1000 towards drains; construction of drainage system
Town (seaside and hillside)	Stagnant water in unlined ditches	Replace open drains with closed or semi-closed drains
	Stagnant water in concrete-lined drains during periods with low rainfall	Provision of narrow central channel to take dry-period flow
Town (hillside)	Stagnant water in depressions, due to seepage from the hills	Provision of hill-foot drains
River	Accumulation of brackish water in silted-up river mouth	River training and construction of piers

The total cost of the sanitation works amounted to Dfl.650,000 (Dfl. = Dutch guilders) at the 1920 price level, or Dfl.3,100 per hectare or Dfl.144 per inhabitant. For comparison, labour wages in 1920 were about Dfl.1 per day and the cost of rice about Dfl.0.10 per kilogram.

After implementation of the works, mortality decreased from 79.5 per 1,000 in 1912, to 18 per 1,000 in 1919, and further to 13.8 per 1,000 in 1922. The spleen index decreased from 98 in 1912, to 50 in 1917, and to 1.9 in 1922 (Nieuwenhuis 1923).

Species Sanitation

Sibolga, like Panama, was an example of complete sanitation: the measures taken were aimed at all species of Anopheline mosquitoes. But in 1911, Watson, working in Malaya, had found that not all Anophelines transmit malaria. He discovered that, in areas where the forest had been cleared for rubber cultivation, malaria had disappeared. Clearing the forest had destroyed the breeding sites of *Anopheles umbrosus*, which require shade, although it did not affect the breeding sites of other Anopheles mosquitoes, which remained in abundance. It appeared that malaria in this area was transmitted only by *Anopheles umbrosus*.

Watson visited Indonesia in 1913, and the malariologists there – the foremost among them being Dr N.H. Swellengrebel – immediately realized the importance of Watson's discovery: instead of having to eliminate all breeding sites, they could control malaria simply by making the environment unsuitable for the local, proven, vector species. Swellengrebel called this 'species sanitation'. Not only would species sanitation cost

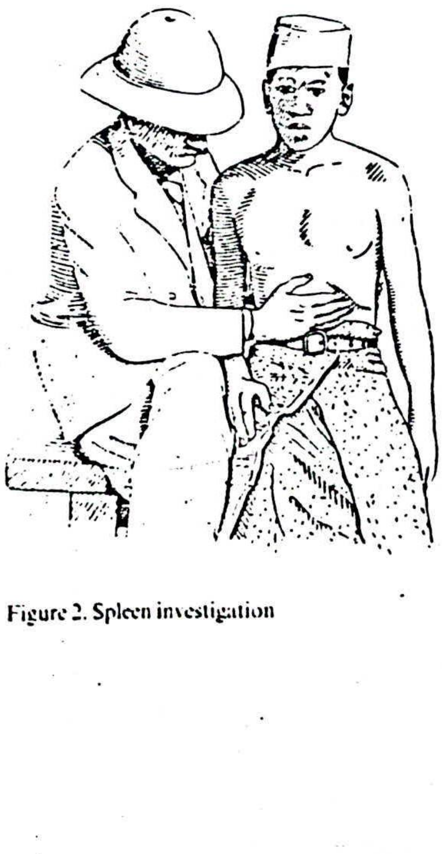


Figure 2. Spleen investigation

much less than complete sanitation, it also provided the means to control malaria in rural areas where the elimination of all breeding sites – such as rice fields and irrigation canals – would have been impracticable.

Species sanitation depends on a knowledge of the local malaria vector and its habits, so this was what Swellengrebel and his colleagues immediately began to study. The first edition of the handbook, *Anophelines in the Dutch East Indies*, was published in 1916. The studies revealed that Anophelines were not always as predictable as Watson had suggested. Only one species – *Anopheles sundaicus* – seemed to be a malaria vector with perfect regularity, whereas other species transmitted malaria in some places but not in others. Because of this unpredictability, every sanitation programme was preceded by a local investigation. A booklet with guidelines for such investigations, prepared by Swellengrebel and Schueffner in 1918, was distributed by the Health Service to Government doctors throughout the Indonesian archipelago. Figures 2 and 3 have been reproduced from this booklet.

Figure 3. Collecting larvae

Irrigated Rice and Malaria: Cihea Plain

The Cihea Plain is a relatively dry plain in West Java, some three hundred metres above sea level. From 1891 to 1904, the Irrigation Department spent about Dfl.1,000,000 on an irrigation system for some five thousand hectares. Upon completion of the irrigation works, many people from other regions emigrated to the Plain. In the first few years, productivity of the land was high and the irrigation water allowed a year-round cultivation of rice. Water management in the area, however, was poor. Even after the harvest, fields remained inundated.

Because of the soil's continuous submergence, soil fertility and yields declined. Also, malaria became a problem. The malaria vector in the Cihea Plain was *Anopheles aconitus*, which prefers sunny breeding places. It does not breed in rice fields when the rice plants have reached a certain stage of growth because the plants produce too much shade. But when the fields remain inundated after the harvest, they become excellent breeding sites. The more yields declined and the more people's health deteriorated because of malaria, the greater the number of fields that remained uncultivated for part of the year and the more breeding sites there were for *aconitus*. The spleen index rose to 90 and the mortality rate increased to 60 per 1,000, which was three times the average figure for Java.

To improve both the agricultural and the health situations, a 'plant and water regulation' was introduced in 1919 (Mangkoewinoto 1923). Under this 'regulation', the following were made mandatory:

- Rice was to be cultivated only from 1 October to 31 May;
- Irrigation water was to be supplied only during that period;
- All fields had to be drained immediately after the harvest.

To implement the 'plant and water regulation', the Irrigation Department improved the field drainage systems and the Health Department provided Dfl.10,000 a year

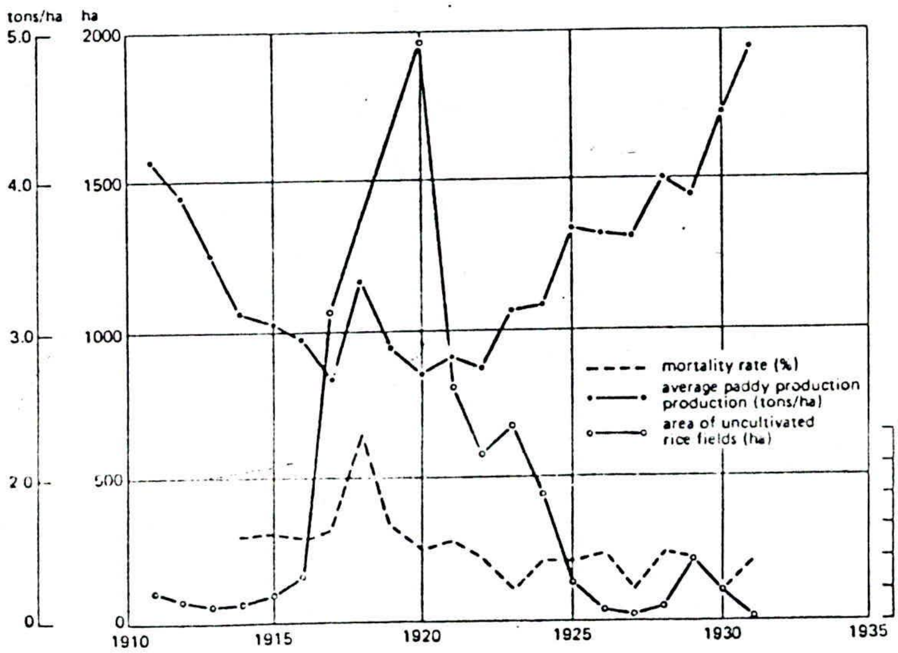


Figure 4. Effects of sanitation measures in the Cihea Plain

to clean the tertiary irrigation and drainage ditches. This task was normally done by the farmers, but they were no longer sufficiently strong to do it properly. So, the Health Department paid the Irrigation Department to maintain the tertiary system.

Figure 4 shows how, after the introduction of the 'plant and water regulation' in 1919, mortality decreased and agricultural productivity improved (Koorenhof 1933).

Figure 5 shows the spleen indices for the children in the villages of the Plain for

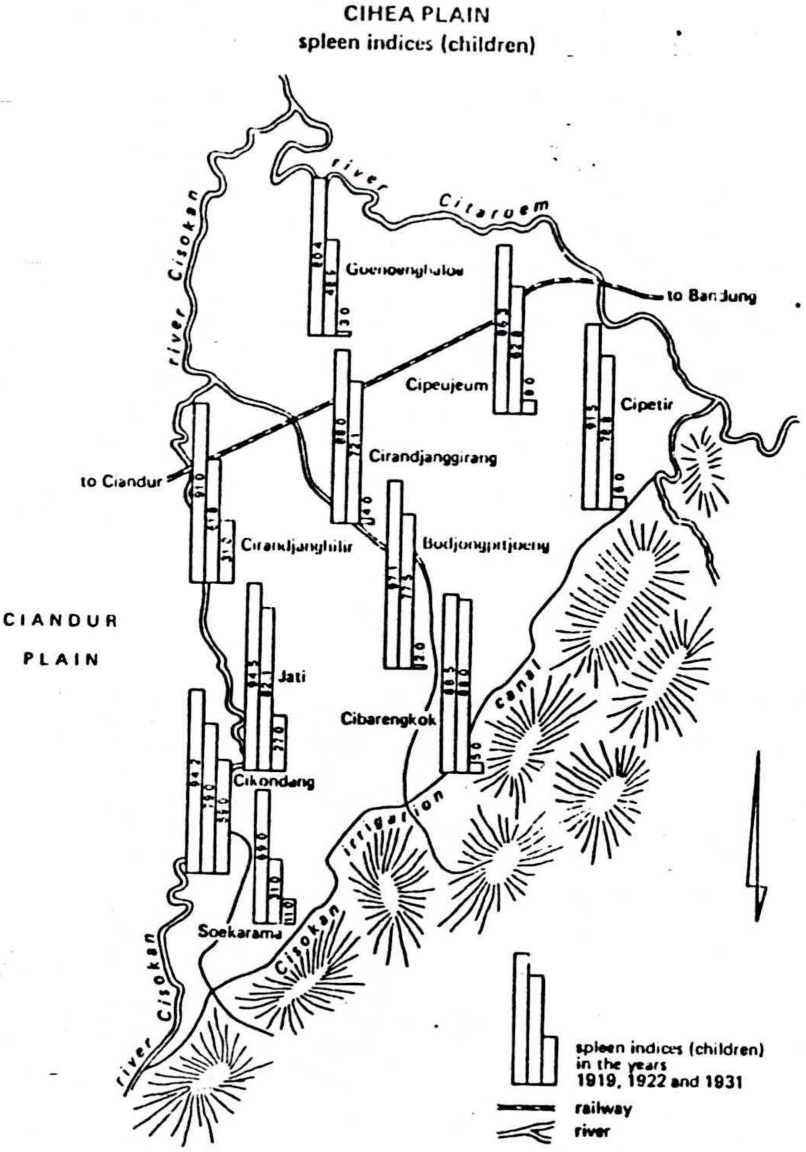


Figure 5. Spleen indices (children) in the Cihea Plain

the years 1919, 1922, and 1931. Although this reveals significantly decreasing spleen indices, in 1931 malaria still prevailed in the western part. This was attributed to the malarious areas in the Cianjur Plain, on the other side of the River Cisokan. There, no 'plant and water regulation' had been implemented because the indigenous irrigation systems on that Plain did not provide sufficient control over the water. But, in the light of the results achieved in the Cihea Plain, it was decided to replace the village-type systems with a 'technical' irrigation system – with separate canals for irrigation and drainage – and to introduce a similar 'plant and water regulation'. The irrigation works for an area of 12,680 hectares started in 1937 and were scheduled for completion in 1939 at a cost of Dfl.460,000 (*Jaarverslag Geneeskundig Laboratorium 1936*).

Lagoons and Malaria: Calang

The success of species sanitation depends greatly on the correct identification of the vector and its breeding site. This is illustrated by the example of Calang, a military camp on the west coast of Sumatra (see Figure 1).

In an effort to control malaria, the Army had begun filling in the swamps around the camp in 1908, but the malaria persisted. In 1934, another army surgeon – called Mulder – was transferred to the camp. After studying the malaria reports, he started to wonder whether perhaps it were not the swamps that caused malaria, but the lagoons. These lagoons had formed in places where the discharge of the rivers was not sufficient to push back the sand that had been deposited in the river mouth during high tides. In the dry season, the sea built up a sandbar, which closed the rivers off from the sea. The brackish water in these lagoons was a suitable breeding place for *Anopheles sundaicus*.

Mulder started to experiment with laying wooden pipes through the sandbars to drain the lagoons. Within four months, he had freed the camp of malaria. The wooden pipes were then replaced by permanent steel pipes at a cost of Dfl.5,000. Quite cheap, considering that the cost of filling the remaining swamps had been estimated at Dfl.100,000. This illustrates that a lot of money can be saved by the correct identification of the vector and its breeding site.

Mangrove Forest and Saltwater Fishponds

The mangrove forests along tropical coasts used to have the reputation of causing malaria. Early this century, in former British Malaya, millions were spent clearing mangrove forests to protect villages and towns from malaria. Most of that money was wasted because the movement of the tide makes a mangrove forest unsuitable as a breeding site. However, when an area of mangrove forest is cut off from the sea by a road or a railway and there is no more tidal movement, an extremely dangerous breeding site is created. This can be prevented by placing sufficient culverts in the road or railway to allow the tide to go in and out.

In Indonesia, mangrove forests were cut for the excavation of saltwater fishponds.

especially near major cities like Jakarta. As there wasn't any tidal movement in the fishponds, they soon became breeding sites for *Anopheles sundaicus*. How dangerous they were is illustrated by Figure 6, which shows the spleen index for the different quarters of Jakarta. The closer to the fishponds, the higher the spleen index was. In 1917, the mortality rate in the quarter closest to the fishponds - Mangga Doca - was 100 per 1,000, five times higher than the average figure for Java.

To control malaria, the Government first wanted to fill in all the fishponds. The cost, however, was estimated at Dfl.25,000,000. This amount was not available, so alternatives had to be found. It appeared that the mosquito deposits its eggs between the floating algae - especially *Enteromorphae* - which provide the larvae with both food and shelter from any larvae-eating fish. This discovery provided the key to the malaria problem in the fishponds: get rid of the floating algae. Draining the ponds once every month killed the algae while stimulating the growth of water plants that rooted in the bottom of the pond. This was essential to provide food for the cultivated fish, which were vegetarian.

The periodic drainage of saltwater fishponds - 'hygienic exploitation' - reduced the cost of their sanitation in Jakarta from Dfl.25,000,000 to Dfl.5,800,000 (Walch and Schuurman 1930).

The hygienic exploitation produced satisfactory results and was applied in many places in Java.

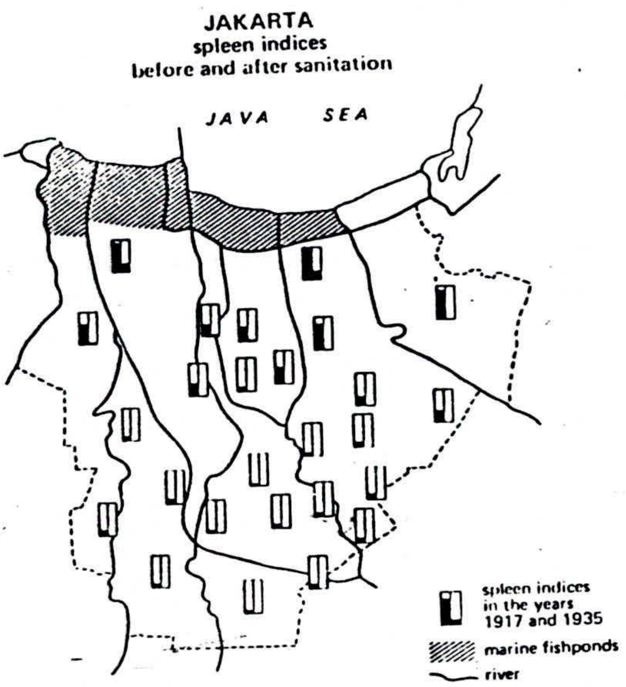


Figure 6. Spleen indices in Jakarta before and after the hygienic exploitation of saltwater fishponds

Saline Rice Fields: Brengkok

In the village of Brengkok, in spite of the hygienic exploitation of the fishponds, a serious outbreak of malaria occurred in 1933 (Figure 7). The cause of the outbreak was that the monsoon rains were later than normal that year. When it finally started to rain, it was too late to plant rice. On the saline rice fields, rainwater was impounded and became brackish. Brackish, stagnant water on uncultivated rice fields is an excellent breeding site for *Anopheles sundaicus*. Once the cause had been identified, the solution was quite simple: when a rice field – for whatever reason – remained uncultivated, the bunds were cut to prevent rainwater from inundating the field.

This shows that the prevention of malaria doesn't always require a substantial investment; in Brengkok, it only needed a simple water-management measure.

The cause of the Brengkok epidemic was not identified through larvae finds by a medical doctor or an entomologist, but by an engineer, Kuipers, who was Chief

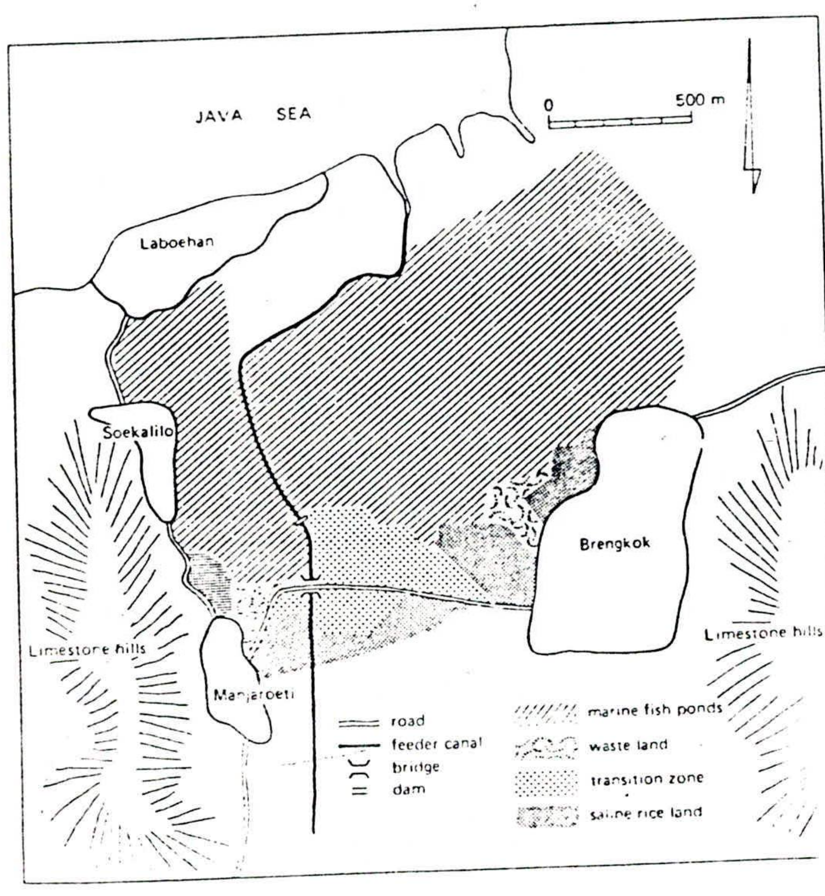


Figure 7. Potential breeding sites for *Anopheles sundaicus* near the village of Brengkok, East Java

Engineer of the Provincial Sanitation Office for East Java. Kuipers used meteorological data and soil characteristics of the saline rice fields to produce a 'ponding curve'. From the ponding curve, he derived a theoretical vector-density curve, which appeared to correspond with the mortality curve of thirty-five days later (Figure 8). This correspondence was taken as evidence that the breeding of *Anopheles sundaicus* in the saline rice fields caused the epidemic (Snellen 1988).

Conclusion

Irrigation and drainage engineers have an important role to play in the control of malaria. Because of the single strategy during the DDT era, engineers in the last decades haven't been consulted much on the control of malaria and other water-related, vector-borne diseases. But because the single strategy no longer works, they can expect to be called upon soon, as they were in the past.

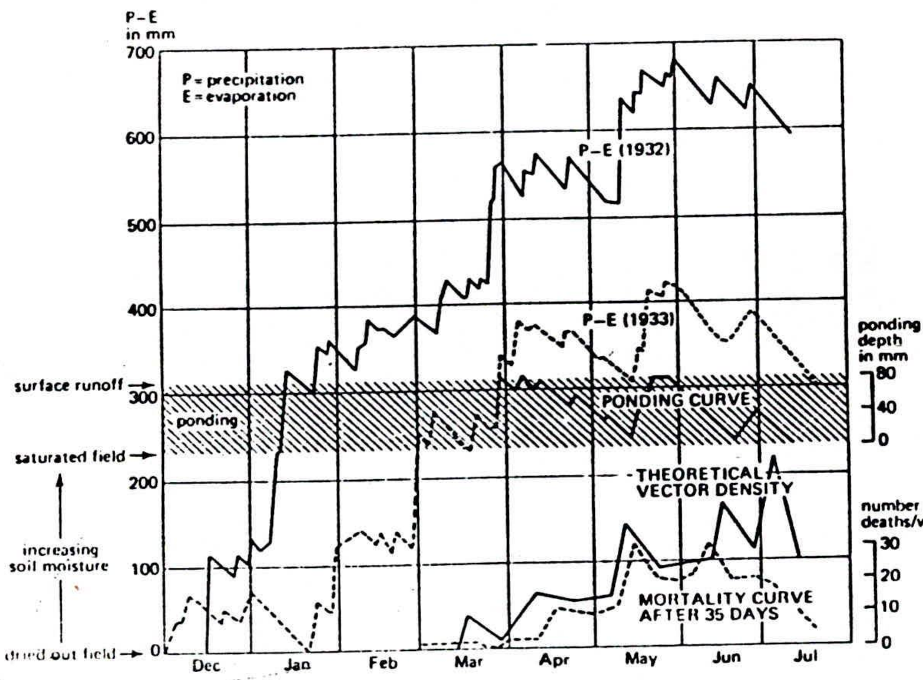


Figure 8. Mortality curve, theoretical vector density, and the ponding curve in saline rice fields near Brengkok, derived from data on rainfall, evaporation, and soils

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ROLE OF FISHES IN VECTOR CONTROL IN INDIA

V.P. Sharma

ABSTRACT

Recent studies have shown that larvivorous fishes can play an increasingly greater role in the control of mosquito breeding and consequent curtailment of transmission of the vector borne diseases. Production of larvivorous fishes is inexpensive as it utilises naturally occurring ponds and it could be linked with the production of edible fishes for better economic gains. A proposal to establish a 50 acre farm of fishes for public health for research and development would strengthen application of biological control of mosquito breeding in the country.

INTRODUCTION

During mid-1970s there was widespread resurgence of malaria in India. Besides large parts of the country have remained endemic for filariasis. Japanese encephalitis epidemics started in 1973 have been visiting newer areas with vengeance. Similarly dengue epidemics have been reported from various parts of the country. The problem of urban malaria started to deteriorate concurrent to malaria resurgence. The National Malaria Eradication Programme (NMEP) of the Govt. of India is responsible for the control of vector borne diseases. The NMEP intensified vector control measures, with particular emphasis on malaria control. The strategy of malaria control in rural areas was to control malaria by residual insecticidal spraying whereas in urban areas anti-larval methods were emphasized under the urban malaria scheme (UMS). This strategy resulted in the curtailment of transmission in many parts of the country while in some regions malaria outbreaks have been reported with deaths due to malaria. This has become a matter of serious concern. Besides <u>P. falciparum</u> incidence has stabilized at about 0.5 million annually and the parasite has become resistant to chloroquine in various states of the country. The control of malaria requires more potent insecticides. At the same time massive quantities of insecticides used in the control of malaria (e.g. DDT (50%) 21000 mt, BHC (50%) 37,000 mt, malathion (25%) 20,000 mt) year after year started to attract public criticism. Insecticides contaminate the food chain and pose a serious health hazard. Besides evolution of physiological resistance in vector species and harmful effects on beneficial fauna resulted in control failures (Sharma 1986a). The environmentally conscious scientists started to question the wisdom of spraying and demanded

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restricted use of insecticides. This lobby is becoming stronger day by day. Besides malaria control by insecticidal application is very expensive and there are instances of the mis-use of insecticides meant for spraying. It may also be noted that inseciticides have limited life span as the mosquitoes develop resistance and eventually multiple resistance develops and effective control of vectors is not achievable even at enormous investments by the government. Besides the cost replacement of insecticides like malathion, fenitrothion or synthetic pyrethroids is invariably prohibitive. With this background there was felt need of the malaria control organization in the country to develop alternative methods of vector control. It may be noted that before launching of the Science and Technology project, although fishes were recommended for biological control under the UMS but sufficient stocks were not maintained almost anywhere in the country. Larvivorous fishes were kept in some urban areas more for demonstration rather than for malaria control, save a few isolated instances. It is noteworthy to mention that nowhere in the country fishes were applied in rural malaria control programme in any meaningful manner.

Field Experiments: In 1983 a strategy on the bioenvironmental control of malaria was conceptualized at the Centre and launched for the first time in Gujarat. This field project was started in Nadiad, Kheda district. The project was aimed to study the feasibility of the bioenvironmental control of malaria in endemic rural areas. The study villages had extensive breeding grounds for a variety of Anopheles and Culex mosquitoes. In particular Anopheles culicifacies, the vector of rural malaria was in abundance. The vector was resistant to DDT, HCH and malathion. Mosquito nuisance was unbearable and there was an outbreak of malaria with deaths due to P. falciparum. In this area environmental modification and manipulation methods in conjunction with Guppy fishes (Poecilia reticulata) brought down the incidence of malaria to low levels which was unattainable by the residual spraying of DDT and malathion (Sharma, 1987). The alternate strategy was found environmentally safe socially acceptable and cost effective (In-depth report, 1987).

Simultaneously, while the field experiments in Kheda were in progress plans were made to initiate similar studies in other geo-epidemiological zones of the country. These projects were launched to test the feasibility of bioenvironmental control of malaria in other areas with problems related to terrain, vectors, parasite and socio-economic and cultural aspects in rural, urban and industrial areas. Because of the fact that feasibility studies showed promise in the bioenvironmental methods in the control of mosquito breeding and interruption of transmission, this strategy was launched under the Science and Technology project in mission mode. The project has the approval of the Prime Minister of India and progress of work is monitored by the Scientific Adviser to the Prime minister. Under this Project 9 field stations were opened in UP, Orissa, MP, Assam and Tamil Nadu. In all areas besides the environmental methods of vector control, fishes were extensively used for the control of mosquito breeding (Sharma et al. 1986, 1987, Singh et al. 1989). In the first instance local fish fauna were surveyed and potential of indigenous fishes was evaluated in the control of mosquito breeding in different habitats (Sharma et al. 1987). The two well known larvivorous fishes are exotic. The Guppy a native of South America was introduced in India in 1908 (Jhingran, 1985). Gambusia affinis a native of Texas and widely distributed in the world was imported in India from Italy in 1928 by Dr.B.A. Rao (Rao, 1984). Guppy (Poecilia reticulata) and Gambusia (Gambusia affinis) have been used in vector control programmes for 5 to 6 decades and could be found widely occurring in nature almost all over the country. Stocks of these fishes were collected, multiplied and introduced in mosquito breeding areas. Experience of project scientists working in different parts of the country on the role of fishes in the control of mosquito breeding is being presented in this workshop. Readers are advised to study these papers in original to get the feel of the quantum of work done on this important aspect of vector control, and how far fishes can be used in the control of vector borne diseases. Some innovative methods have also been developed to reduce cost of mass production and distribution. Besides larvivorous fish production has been linked with edible fish production as an incentive to generate income for the village communities (Gupta et al.1989). This income has been used in the control of mosquito breeding and in other schemes of environmental improvement (Sharma et al. 1989).

Future prospects : In India the main mosquito transmitted diseases are malaria, filaria, Japanese encephalitis and dengue. At present there are about 2 million cases of malaria, and of these about 60-70% malaria cases are transmitted by Anopheles culicifacies and 10-15% by Anopheles stephensi. Remaining transmission (10-20%) is maintained by other 7 or 8 vectors which are of local importance. A. culicifacies is the vector of rural and peri-urban malaria. It breeds on ground in a variety of habitats such as ponds, puddles, hoof prints, rice fields, irrigation channels, seepage water and marshy areas etc. There is a sudden spurt of its populations with the onset of monsoon as rain water provides ideal breeding habitats in vast areas. A. stephensi breeds in wells, overhead tanks, cisterns and rain water puddles. Recent experiments have shown that fishes can be applied in the control of both the vector species. Fishes could also be applied in the control of other malaria vectors but large scale field application may require selection of situation specific strains and further research. In regard to filariasis, there are about 360 million people exposed to its risk with 18 million microfilaria carriers and 8 million with manifestation of the disease. The vector of Wuchereria bancrofti, Culex quinquefasciatus breeds profusely in polluted water in all rural and urban areas and the disease is expanding to newer areas around towns such as Lucknow, Vellore (Abdulcader, 1962) and U.P terai (Sharma, 1986b). This mosquito also constitutes the bulk of mosquito population responsible for high nuisance in and around rural/ and urban areas. Besides, a small focus is maintained in Kerala and some other pockets of Brugia malayi infection transmitted by Mansonia annulifera. The mosquito breeds in ponds infested with pistia plants.

Fishes used in the control of mosquito breeding in the world are given in Table 1 and their distribution is shown in map 1 (Source, WHO 1982). Fishes have been used in India in the control of mosquito breeding in a variety of habitats (Sitaraman et al. 1976, Menon and Rajagopalan 1977, Sharma et al. 1987) and there are strains of guppy fishes surviving for more than a decade in polluted drains (P.B. Deobhankar, Personal communication). Grass carps have also been used in the control of water weeds. If introduced they not only clean up the vegetation from ponds but keep the margins free of grasses and maintain the ponds free of any vegetation growth. The Japanese Encephalitis (JE) is transmitted by Culex vishnui group of mosquitoes and the disease occurs in sporadic form. The vector mainly breeds in rice fields. So far there has been no effective method of the control of mosquito breeding in rice fields that can be applied in vast rural areas. Of the many methods tested for the management of vector breeding in rice fields fishes, hold good promise. Dengue is transmitted by Aedes aegypti. The vector breeds in urban areas in overhead water tanks, cisterns and a variety of containers. In many situations fishes can control mosquito breeding if a proper monitoring system is established. It is noteworthy to mention that for the first time ever fishes were used for the control of Aedes aegypti in Havana at the turn of century.

In addition to disease vectors, stagnant water all over the country produces enormous mosquito populations. These mosquitoes bite frequently and create unbearable nuisance. Fishes can play a major role in controlling mosquito proliferation, thus curtailing nuisance and disease transmission.

Our studies in various parts of the country have shown that in times to come larvivorous fishes will play major role in the control of mosquito breeding to interrupt disease transmission. This conclusion is based on the fact that insecticidal application would have limited role in the future in managing the control of mosquito populations. There would be a variety of semi-permanent and permanent water bodies such as ponds, lakes, wells, stagnant water pools, seepage water and rain water collections which would produce enormous mosquito populations. Besides poor drainage and drains with city waste water would constitute another important source of mosquito production. Most of these places can be tackled by the application of larvivorous fishes (See Fig. 1 to 17 on the application of larvivorous fishes in the control of mosquito breeding). It is understood that no single fish species can meet the requirement of a wide variety of situations that exist in terms of mosquito breeding, but fishes could be selected for specific situations. This would also be the cheapest method of vector control and produce long term impact in suppressing mosquito populations. It is therefore necessary to intensify research on various aspects of fish biology and its role in mosquito control.

Genetic Resource Unit : Malaria Research Centre has surveyed local fauna of fishes at its field stations located in various parts of the country. Besides, the two exotic fishes guppy and gambusia local fishes (Rasbora, Oryzias, Colisa, Esomus) have been found as good larvivorous fishes but require further studies on their biology and application in the control of mosquito breeding. The Centre has intensified efforts to discover fishes for certain special situations such as the rice fields, slow moving streams, river bed, canal, polluted drains, annual fishes that can survive the dry season through the eggs which can withstand dessication and start breeding with the onset of rains, fishes that can withstand extremes of temperature, turbidity and salinity. Unfortunately at present no indigenous fish has been shown to be suitable for above situations. Experience so far has shown that introduction of fishes wherever they survive completely eliminates mosquito breeding, provided they can survive long enough, negotiate the grassy margins or penetrate the weeds etc. Fishes are highly successful in the control mosquito breeding at low cost and without any adverse impact on the environment such as are faced with the application of insecticides. The technology requires very small budget mainly for supervision and transportation and the fishes breed in natural ponds without any special care. Because of simplicity of technology and ease with which fishes can be handled and introduced in water bodies communities can play a major role in the maintenance of hatcheries and distribution in rural areas. There is therefore a felt need and great scope for exploitation of fishes in vector control programme all over the country.

At present in India or elsewhere there is no centre exclusively devoted for basic and applied studies on larvivorous fishes. There is an urgent need to develop such a genetic resource unit where fishes from India and abroad could be tested for their potential in the control of mosquito breeding under a variety of environmental stresses. Methods should also be developed for their distribution and maintenance of stocks at low cost. A systematic study of larvivorous fishes and their impact on the environment could be of great value in controlling mosquito breeding in different epido-climatic zones of the country.

In order to achieve this objective it is proposed to establish a 50 acre genetic resource unit on fishes for public health at a suitable place in the country with modern research and expansion facilities. The main unit would have satellite centres at the field stations where fishes requiring special climatic conditions could be maintained. The unit would perform the following functions.

1. Collection of indigenous and exotic fishes from all over the world and maintenance of genetic stocks. Exotic fishes will

be imported only after obtaining clearance from the Govt. of India.

2. Research and development

3. Reference Centre for larvivorous fishes

4. Establishment of linkages both national and international

5. Training

6. Fish distribution in the country.

7. Preparation of health education material.

8. Consultancy services

It is envisaged that the main unit and field stations would carry out the following research and development activities.

(i) Biology of fishes and their nutritional requirements.

(ii) Maintenance of genetic stocks in acquarium and ponds etc.

(iii) Development of appropriate technology for mass production of fishes in rural areas as well as urban centres.

(iv) Tests on the larvivorosity of fishes.

(v) Development of methods for packaging, transportation, release, and re-distribution by establishing local hatcheries.

(vi) Establishment of decentralized hatcheries of larvivorous fishes all over the country for use in mosquito control programmes.

(vii) Selection of fishes or sub-species of known larvivorous fishes that can withstand extremes of turbidity, pH, temperature, salinity etc.

(viii) Selection of fishes for weed control e.g. water hyacinth and fungi/algae etc.

(ix) Composite fish culture.

(x) Methods of manuring fish ponds and cleaning of ponds from weed fishes.

(xi) Ecological impact of the introduction of exotic fishes in regard to other fish fauna and non-target organisms.

The above proposal has been approved by the Govt. of India. It is noteworthy to mention that this would be the first facility of its kind anywhere in the world.

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India mark II hand pumps have been installed by UNICEF in many parts of the country to provide potable water in rural areas. The installed sites have no provision of drainage (Fig. 1). In this case a drain was prepared and waater collected in a pit in Mandla district, MP (Fig. 2). This site is used as hatchery for the production *Poecilia reticulata* for the supply of fishes to nearby areas.

In Nadiad kheda district Gujarat village ponds are used for the production of carps along with the larvivorous fish Guppy. The scheme was launched to encourage edible fish production as an incentive along with the control of mosquito breeding and production of guppies for distribution to other ponds. Fig. 4 shows the collection of fishes from a pond and Fig. 5 shows edible fishes ready for auction.

Health education is an important component of the bioenvironmental control of malaria strategy. Fig. 6 shows a group of students visiting a laboratory in Nadiad field station to study the role of larvivorous fishes in the control of mosquito breeding and Fig. 7 shows a health education camp delivering a lecture in Mandla village on the application of biological and environmental management methods in the control of mosquito breeding.

Guppy and Gambusia fishes are mass produced in village ponds. A pond in Shahjahanpur village is being prepared for production of Gambusia fishes. Weeds and predatory fishes are removed and margins are cleaned and vertically cut (Fig. 8). Abandoned cement tanks are also used as hatcheries as shown in Fig. 9 from a village in Nadiad, Gujarat.

Fig. 10 and 11 shows a view of the nothing of Gambusia from a village pond in Shahjahanpur.

Gambusia or Guppy fishes are collected from the hatcheries and transported in a bucket for short distances (Fig. 12) or in a truck and released in a variety of mosquito breeding sites such an underground cement tank in Haldwani (Fig. 13).

Fishes are used to control mosquito breeding in a variety of habitats in rural and urban areas such as a well in shahjahanpur (Fig. 14) a pond in Shankargarh, Allahabad (Fig. 15) a cement tank in Haldwani (Fig. 16) and a drain in Mandla (Fig. 17).

Table : 1 KNOWN AND POTENTIAL LARVIVOROUS FISHES

ZONE AND COUNTRIES	Mediterranean and Near East (including Afghanistan & Iran)	Spain, Morocco	South-East Asia
FISH AND THEIR BIONOMICS			
Family	Cyprinodontidae	Cyprinodontidae	Cyprinodontidae
Genus and Number of Species	Aphanius, 12 spp.	Valencia, 1 sp.	Aplocheilus, 6 - 7 spp.
Better Investigated Species	dispar, sophiae, mento	hispanica	lineatus, dayi, blocki, panchax
Size (in cms.)	5 - 10	8 - 10	5 - 12
Dimorphism of sexes	Intermediate	Little	Intermediate
Type of spawning	On plants and substratum	On plants and substratum	On plants and substratum
Food	Omnivorous	Omnivorous	Carnivorous
Incubation period (in days)	7 - 10	12 - 14	14
Resistance of eggs to dessication	Not resistant	Not resistant	Not resistant
Size of Fry	Of medium size	Big	Big
Rate of Growth	Rapid	Rapid	Rapid
Position of Mouth	Superior	Superior	Superior
Breeding Period	Year round (depends on temperature)	Year round (depends on temperature)	Year round (depends on temperature)
Habitat	Streams, lakes, pools, ponds	Streams, lakes, pools, ponds	Lentic
CHEMISTRY OF WATER			
pH	6 - 8	6 - 8	6 - 8
^{o}dH	Hard water	Hard water	Moderate hardness
Salinity	Tolerant to sea water	Tolerant to sea water	Not very tolerant
Organic Pollution	Resistant	Resistant	Resistant
TEMPERATURE			
Max. range (in Deg. C)	8 - 40	10 - 25	18 - 40
Min. (for breeding) (in Deg. C)	18 - 25	16 - 18	23 - 28
REMARKS	Very adaptable, hardy, voracious feeders	Tolerate cooler waters, voracious feeders	Surface feeders

ZONE AND COUNTRIES	SOUTH-EAST ASIA	SOUTH-EAST ASIA	SOUTH-EAST ASIA
FISH AND THEIR BIONOMICS			
Family	Cyprinodontidae	Cyprinidae	Hemirhamphidae
Genus and number of Species	Oryzias, 10 spp.	Chela, Rasbora, Barbus (Puntius), Danio, Brachydanio, Esomus, Osteobrama	Hemirhamphus, Dermogenys
Better Investigated Species	melastigma, javanicus latipes	Many species in each genus	Few species in every genus
Size (in cm.)	3-4	2-10	4-10
Dimorphism of sexes	Very little	Almost none	Little
Type of spawning	On plants, eggs in clusters	On substratum	Viviparous
Food	Carnivorous	Omnivorous	Carnivorous
Incubation period (in days)	3-5	1-4	0
Resistance of eggs to dessication	Not resistant	Not resistant	0
Size of Fry	Very small	Small or of medium size	Big
Rate of Growth	Slow	Slow	Rapid
Position of Mouth	Superior	Terminal	Superior
Breeding Period	Year round (depends on temperature)	Rainy season	Year round
Habitat	Primarily still water	Streams, stagnant water, rivers, lakes	Lagoons and in fresh reservoirs
CHEMISTRY OF WATER			
pH	7-9	6-8	7-9
^{0}dH	Hard water	Soft	Very hard
Salinity	Tolerant to salinity	Not tolerant	Tolerant to sea water
Organic pollution	Resistant	Some can withstand, but generally poor	Resistant
TEMPERATURE			
Max. ranges (in ^{0}C)	18-40 : 1-40(latipes)	18-40	18-40
Min.(for breeding)(in ^{0}C)	23-28 :18-22(latipes)	23-28	23-28
Remarks	Surface feeders	Surface and shoaling feeders	Surface feeders

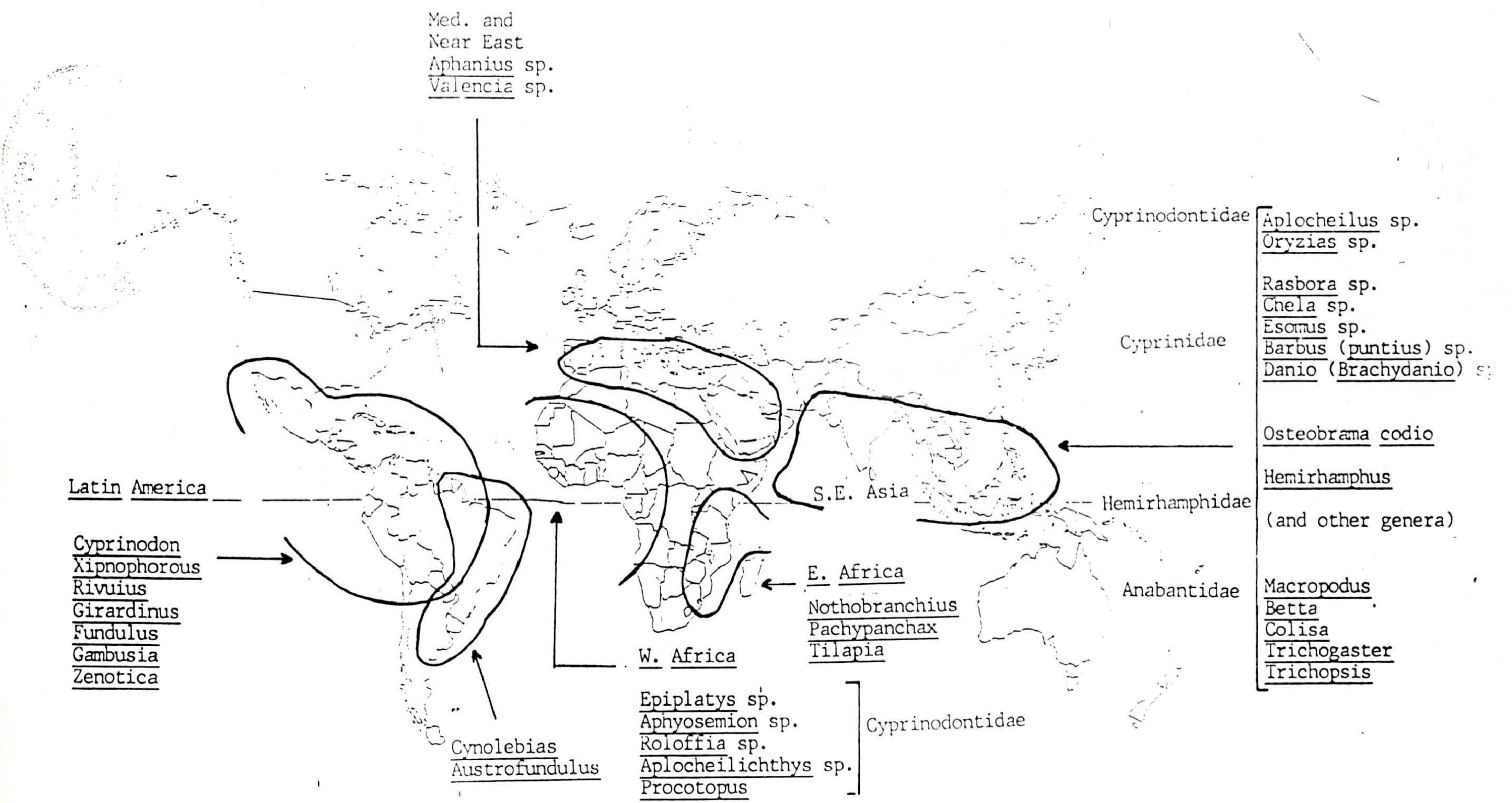
ZONE AND COUNTRIES	South-East Asia	West Africa	West Africa
FISH AND THEIR BIONOMICS			
Family	Anabantidae	Cyprinodontidae	Cyprinodontidae
Genus and Number of Species	Macropodus, Betta, Colisa Trichogaster, Trichopsis	Aphyosemion, 60 spp.	Roloffia. 20 spp.
Better Investigated Species	Many species in each genus	calliurum, gardneri, sjostedti	occidentalis, geryi
Size (in cms.)	3 - 15	5 - 12	5 - 10
Dimorphism of sexes	Strong	Strong	Strong
Type of spawning	Nests of water surface Bubbles usually made by male	On plants, On substratum	On plants, On substratum
Food	Carnivorous	Carnivorous	Carnivorous
Incubation period (in days)	2 - 3	1) 14 2) 1 - 4 months	1) 14 2) till 9 months
Resistance of eggs to dessication	Not resistant	partially resistant	1) Partially resistant 2) resistant
Size of Fry	Small	Small or of medium size	Small or of medium size
Rate of Growth	Slow	Rapid	Rapid
Position of Mouth	Terminal	Superior	Superior
Breeding Period	Year round	Year round	Year round
Habitat	Slow warm reservoirs and in slow streams	Slow streams, pools, ponds	Slow streams, pools, ponds
CHEMISTRY OF WATER			
pH	6 - 9	5.5 - 7.5	5.5 - 7.5
^{o}dH	Soft and hard water	Soft	Soft
Salinity	Slightly tolerant	Some spp. slightly tolerant	Some spp. slightly tolerant
Organic Pollution	Very resistant	Resistant	Resistant
TEMPERATURE			
Max. range (in Deg. C)	20 - 40	15 - 35	15 - 35
Min. (for breeding) (in Deg. C)	23 - 30	20 - 25	20 - 25
REMARKS	Air breathing, easily transported	Males may be territorial, surface feeders	Males may be territorial, surface feeders

ZONE AND COUNTRIES	West Africa	West Africa	West Africa
FISH AND THEIR BIONOMICS			
Family	Cyprinodontidae	Cyprinodontidae	Cyprinodontidae
Genus and Number of Species	Epiplatys, 30 spp.	Aplocheilichthys, 50 spp.	Procatopus, 10 spp.
Better Investigated Species	fasciolatus, dageti, chaperi		gracilis
Size (in cms.)	3 - 10	2 - 6	5 - 8
Dimorphism of sexes	Strong	Little	very little
Type of spawning	On plants	On plants	On plants
Food	Carnivorous	Carnivorous	Carnivorous
Incubation period (in days)	14 days	10 - 18	10 - 14
Resistance of eggs to dessication	Not resistant	Not resistant	Not resistant
Size of Fry	Small	Small	Small
Rate of Growth	Rapid	Rapid	Rapid
Position of Mouth	Superior	Superior	Superior
Breeding Period	Year round	Year round	Year round
Habitat	Slow streams, pools, ponds	Slow streams, pools, ponds	More rapid streams
CHEMISTRY OF WATER			
pH	6 - 8	5 - 7.5	6 - 8
°dH	Soft and hard	Soft	Soft
Salinity	Slightly tolerant	Slightly tolerant	Slightly tolerant
Organic Pollution	Resistant	Not resistant	Not resistant
TEMPERATURE			
Max. range (in Deg. C)	15 - 35	16 - 30	16 - 30
Min. (for breeding) (in Deg. C)	20 - 25	20 - 25	20 - 25
REMARKS	Surface feeders	Surface feeders	Surface feeders

ZONE AND COUNTRIES	East Africa	East Africa	East Africa
FISH AND THEIR BIONOMICS			
Family	Cyprinodontidae	Cyprinodontidae	Cichlidae
Genus and Number of Species	Nothobranchius, 20-25 spp.	Pachypanchax, 2 spp.	Tilapia, more than 20 spp.
Better Investigated Species	quentheri, orthonotus, patrizii, korthausae	playfairi, pomalonotus	nilotica, mossambica, zilli
Size (in cm)	5-8	6-10	
Dimorphism of sexes	Strong	Little	
Type of spawing	in substratum	On plants	on substratum, some carry eggs in the mouth
Food	Carnivorous	Carnivorous	Carnivorous or herbivorous or omnivorous
Incubation period (in days)	20 days - 1 year (eggs require drying)	14	
Resistance of eggs to dessication	Resistant	Not resistant	Not resistant
Size of Fry	Small	Of medium size	Large
Rate of Growth	Extremely rapid	Extremely rapid	Rapid
Position of Mouth	Superior	Superior	Terminal
Breeding Period	Year round	Year round	Well-known genus, species variable
Habitat	Temporary ponds	Streams, pools, ponds	
CHEMISTRY OF WATER			
pH	6-8	6-8	6-8
°dH	Soft and hard	Soft and hard	variable, tolrerant
Salinity	Tolerant	Very tolerant	
Organic Pollution	Resistant (Very tolerant to extremes)	Resistant	Resistant
TEMPERATURE			
Max. range (in °C)	16-30	18-35	10-40
Min. (for breeding) (in Deg. C)	20-25	23-28	18-28
REMARKS	"Annual" voracious feeders	Voracious feeders	Can be a food fish

ZONE AND COUNTRIES	Latin America	Latin America	Latin America
FISH AND THEIR BIONOMICS			
Family	Cyprinodontidae	Goodeidae	Poecillidae
Genus and Number of Species	Cynolebias, 20 spp.	Xenotoca, Goodea, Neotoca	Gambusia, Poecilia, Girardinus, Xiphophorus
Better Investigated Species	belottii, adloffi, elegans	X. eiseni	Many species in each genus
Size (in cms.)	4 - 12	6 - 14	2 - 8
Dimorphism of sexes	Strong	Marked	Males with gonopodium (anal fin in the shape of tube)
Type of spawning	in substratum	Viviparous	Viviparous
Food	Carnivorous	Omnivorous	Omnivorous
Incubation period (in days)	2 - 5 months (eggs require drying)	0	0
Resistance of eggs to dessication	Resistant	0	0
Size of Fry	Big	Very big	Big
Rate of Growth	Very rapid	Very rapid	Very rapid
Position of Mouth	Terminal	Terminal	Superior
Breeding Period	Year round	Production of fry about 50 days, (X. eiseni)	Year round, production of fry about 4 weeks
Habitat	Temporary pools	Streams, ponds, lagoons	Streams, ponds
CHEMISTRY OF WATER			
pH	6 - 8	6 - 8	6 - 8
°dH	Soft and hard	Hard	Hard
Salinity	Slightly tolerant	Very tolerant	Tolerant
Organic Pollution	Resistant	Resistant	Resistant
TEMPERATURE			
Max. range (in Deg. C)	5 - 40	5 - 40	10 - 35
Min. (for breeding) (in Deg. C)	18 - 25	20 - 25	20 - 25
REMARKS	Very vigorous	Very active feeders	Poecillia and Gambusia well known

Source : WHO Ref. WHO/VBC/82.838 (Reproduced).



MAP 1 : MAP SHOWING THE DISTRIBUTION OF LARVIVOROUS FISHES

Source :WHO Ref. WHO/VBC/82.838 (Reproduced)

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11

Studies on the Role of Indigenous Fishes in the Control of Mosquito Breeding

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Rural malaria control is based primarily on the spraying of residual insecticides to interrupt transmission and treatment of malaria cases to eliminate the parasite reservoir. The bio-environmental strategy of malaria control being employed in Nadiad lays primary emphasis on control of mosquito breeding combined with intensive fever surveillance. Among biological control agents, fishes occupy the foremost position due to their effectiveness in the control of mosquito breeding, and the ease with which they can be mass produced, transported and released in a variety of habitats.

Fish fauna survey in 20 experimental villages of Nadiad taluka revealed the presence of 27 types of fishes. The fishes were identified by the keys of Hora and Mukerji (1937) and Jhingran (1975). These fishes were found in temporary pools, wells, a variety of ponds, seepage water, canal and river etc. Eight fishes were distributed widely in many water bodies. Two species of top minow (*Aplocheilus lineatus* and *Aplocheilus panchax*) and guppies (*Poecilia reticulata*) were most commonly encountered. In semi-permanent water bodies 3 additional types of fishes were found. Permanent water bodies had the richest fauna i.e., 24 species of fishes, whereas the canal and river yielded 19 and 16 types of fishes respectively (Table 1). Though the fishes of India have been studied quite extensively (Prasad and Hora, 1936) and there are several accounts of their distribution, habitat and feeding habits e.g., freshwater fishes of Bombay and Karnataka (Gideon *et al.*, 1937) this is the first account of fish fauna of Kheda district. Of particular interest was the wide distribution of *Aplocheilus lineatus*, *A. panchax* and *Poecilia reticulata* which have been well documented as excellent larvivorous fishes and of these *A. lineatus* was reported to be the fish most suitable for the control of mosquito breeding in a variety of habitats (Hora and Nair, 1938; John, 1940).

During 1985 hatcheries established in the village ponds in 20 villages produced enough guppies for 100 villages. Our field experience shows that production of guppies is easy to accomplish. Although top minnow fishes can also be produced and transported with equal ease, these fishes are heavily preyed upon by a variety of birds. This decimates their population in natural habitats.

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Table 1. Fishes of study villages

Species	Temporary	Semi-permanent	Permanent	Canal	River
Aplocheilus lineatus	+	+	+	+	+
Aplocheilus panchax	+	+	+	+	+
Ambassis nama	–	–	–	+	–
Chela bacaila		–	+	+	+
Catla catla		–	+	–	–
Cirrhina latia		–	+	–	–
Cirrhinus mirgala	–	–	+	–	–
Cirrhinus reba	+	+	+	+	+
Channa punctatus	+	+	+	+	+
Channa sp.	–	+	+	+	+
Glossogobius sp.	–	–	+	+	+
Heteropneustes fossilis	–	+	+	+	+
Labeo rohita	–	–	+	–	–
Mastocembelus armatus	–	–	+	+	–
Mastocembelus pancalus	–	–	+	+	–
Mystus punctatus	–	–	+	–	–
Mystus seenghala	–	–	+	+	+
Notopterus notopterus	–	–	+	+	+
Ompok bimaculatus	–	–	+	–	–
Poecilia reticulata	+	+	+	+	+
Puntius sp.	–	–	+	+	+
Puntius stigma	–	+	–	–	–
Puntius ticto	+	+	+	+	+
Rasbora daniconius	+	+	+	+	+
Trichogaster fasciatc	+	+	+	+	+
Wallago attu			+		
Xenentodon cancila				+	+
Total	**8**	**11**	**24**	**19**	**16**

Laboratory tests were conducted in plastic containers (6 litres) containing 5 fishes each (except *Notopterus notopterus* [1 fish] and *Mastocembelus pancalus* and *Cyprinus carpio* [4 fishes each]). Four hundred IV instar anopheline larvae were introduced in the containers on the first day; those that survived 24 hours later were counted and the number made upto 400 again. The experiment lasted four days.

Tests on larvivoracity revealed (Table 2) that two fishes viz., *Mastocembelus pancalus* and *Xenentodon cancila* did not consume any larvae. *Poecilia reticulata* fed on an average 40.5 larvae per day while all other fishes consumed 60 to 80 larvae per day. *Mystus seenghala* consumed 132 larvae per day. *Notopterus notopterus* consumed 371 larvae per day which was the highest number recorded among the 16 species tested.

For outdoor experiments cement tanks (80 × 80 × 75 cm) were filled three fourths with water. Eight types of fishes were tested on *Culex* and *Anopheles* larvae. Mosquito larvae were introduced in the tanks and their density was estimated (average of 5 dips) daily for 6 days.

Results of outdoor experiments are given in Table 3. The study revealed that feeding capacity of fishes was reduced in presence of

Table 2. Laboratory tests for larvivoracity

Fishes	Size in cms.	Fishes (Nos.)	Number of mosquito larvae consumed					
			Day 1	Day 2	Day 3	Day 4	Total	Average*
Aplocheilus lineatus	2.5–3.0	5	400	400	334	400	1534	76.6
Aplocheilus panchax	2.5–3.0	5	396	260	175	354	1185	59.2
Chela bacaila	3.0–4.0	5	400	400	400	400	1600	80.0
*Cyprinus carpio***	2.0–5.0	4	400	400	400	400	1600	80.0
Channa punctatus	6.0–10.0	5	399	400	400	400	1599	80.0
Cirrhinus reba	3.0–4.0	5	391	382	400	400	1573	78.6
Glossogobius sp.	3.0–3.5	5	260	327	191	400	1178	58.8
Mastocembelus pancalus	5.0–5.0	4	0	0	0	0	0	0
Mystus seenghala	4.0–7.0	3	386	396	400	400	1582	132.0
Notopterus notopterus	15.0	1	360	367	393	365	1485	371.0
Poecilia reticulata	2.5–3.0	5	350	100	130	330	810	40.5
Puntius sp.	3.0–3.5	5	320	363	388	400	1471	73.6
Puntius ticto	4.0–5.0	5	400	400	400	400	1600	80.0
Rasbora daniconius	3.0–4.0	5	400	400	400	400	1600	80.0
Trichogaster fasciata	4.0–6.0	5	400	400	400	400	1600	80.0
Xenentodon cancila	21.0–23.0	5	0	0	0	0	0	0

* Average larvae consumed day/fish
** Chinese or common carp

aquatic vegetation, although the margins were clean and the fishes were able to reach all corners of the tank. The larval density was reduced to very low numbers in a 5 to 6 day period. *Mystus seenghala* consumed the larvae very quickly followed by *Puntius ticto*. The known larvivorous fishes *Aplocheilus* and *Poecilia* also reduced the mosquito densities in ponds to low levels but these fishes were found inferior to *Mystus* and *Puntius*. In the absence of vegetation, the preference was more pronounced for *Anopheles* than *Culex* larvae. This may be due to better visibility of *Anopheles* larvae which float on the water surface. In the absence of vegetation, the rate of consumption was high and almost all the larvae were eaten away in four days (Table 3). Though *Gambusia* has been credited for reducing malaria transmission in the Ukraine (Gerberich and Laird, 1968), WHO (1982) and Hulbert *et al.* (1972) disfavour it because of its adverse ecological impact. Fisheries departments in India also discourage the use of *Gambusia*. It was not found in rural areas of Kheda district, although it is used in the urban malaria scheme in Gujarat. *Gambusia* was not studied in the present experiments.

Field experiments were carried out to study the impact of cleaning the margins of ponds. Larval density was ascertained using a dipper 24 hours before and after cleaning the margins and results were compared against ponds with unclean margins.

Results of field studies revealed that there was considerable reduction in the larval density within 24 hours i.e., average reduction in density was 52%, 39% and 28% in January, February and September respectively (Table 4). The importance of cleaning the margins was therefore clearly demonstrated and incorporated as an important measure in the biological control of mosquito breeding using fishes (Sharma and Sharma, 1986).

Kheda district has a large number of ponds. Fish fauna of these ponds is rich but these ponds also support moderate to heavy mosquito breeding. The ponds were never cleaned or properly maintained by the village Panchayats. Although fishes were being collected from these ponds and occasionally auctioned by the Panchayats the production was negligible. The ponds were

Table 3. Larvivoracity test of fishes in cement tanks

Species	Size in cms.	Fishes (Nos.)	Mosquito Species	Larval density per dip						
				Day 0	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6
(with aquatic vegetation)										
Aplocheilus panchax	2.5–3.0	5	An.	35.0	32.5	28.2	23.2	19.2	14.4	9.2
			Cx.	10.8	4.4	2.2	2.0	1.6	1.2	1.0
Channa punctatus	6.0–10.0	5	An.	38.2	17.6	15.2	9.0	7.6	5.2	3.6
			Cx.	13.0	3.2	2.2	1.8	1.2	1.0	1.0
Cirrhinus reba	3.0–4.0	5	An.	28.0	27.4	20.4	15.2	5.6	3.6	2.0
			Cx.	25.0	23.6	19.8	12.6	5.4	1.4	1.0
Heteropneustes fossilis	7.0–12.0	5	An.	26.2	12.4	4.0	1.6	1.2	0.4	0
			Cx.	1.0	1.0	1.0	0.6	0.4	0	
Mystus seenghala	4.0–7.0	2	An.	47.2	35.4	28.0	13.2	5.0		
			Cx.	5.6	4.2	1.0	0.4	0		
Poecilia reticulata	2.5–3.0	5	An.	33.8	32.0	30.4	22.6	13.4	10.6	5.4
			Cx.	7.6	4.0	2.2	2.2	1.2	1.0	0.2
Puntius ticto	4.0–5.0	5	An.	35.8	8.2	5.0	2.2	1.0	0	
			Cx.	8.4	5.2	1.0	0.6	0		
Trichogaster fasciata	4.0–6.0	5	An.	31.8	12.8	10.6	5.2	4.2	3.0	2.2
			Cx.	7.2	1.8	1.6	1.0	1.0	1.0	1.0
Control			An.	33.3	31.2	30.6	28.2	26.0	24.4	21.2
			Cx.	23.2	19.2	18.0	15.4	14.2	12.0	10.2
(without aquatic vegetation)										
Aplocheilus panchax	2.5–3.0	5	An.	54.0	28.4	19.2	7.2	2.4		
			Cx.	67.8	62.6	53.2	50.6	18.2		
Channa punctatus	6.0–10.0	5	An.	28.4	5.6	2.0	0			
			Cx.	53.6	33.2	3.4	0			
Cirrhinus reba	3.0–4.0	5	An.	43.6	20.2	0.4	0			
			Cx.	60.4	52.0	32.2	29.0	9.4		
Heteropneustes fossilis	7.0–12.0	5	An.	74.8	2.6	0				
			Cx.	48.2	1.0	0				
Mystus seenghala	4.0–7.0	2	An.	51.8	16.4	3.0	0.8	0		
			Cx.	51.8	36.0	22.4	19.6	6.6		
Poecilia reticulata	2.5–3.0	5	An.	54.2	36.0	21.4	5.6	1.6		
			Cx.	48.6	43.5	40.6	38.2	8.0		
Puntius ticto	4.0–5.0	5	An.	39.2	12.4	0				
			Cx.	43.0	35.2	4.6	2.2	0		
Trichogaster fasciata	4.0–6.0	5	An.	63.2	8.2	2.2	1.2	0		
			Cx.	66.6	45.4	15.0	0			
Control			An.	52.4	50.2	47.6	46.0	44.8		
			Cx.	66.4	64.8	63.2	61.4	47.0		

cleaned and guppies were introduced to control mosquito breeding. A scheme for the composite culture of food fishes and prawns along with larvivorous fishes was implemented in 8 village ponds. The ponds were thoroughly cleaned of all types of fishes. Fries, fingerlings and juvenile prawns purchased from the inland fisheries department were then introduced and fish food was occasionally provided for optimum growth. At the end of one year the ponds were auctioned.

Table 4. Impact of cleaning the margins of ponds on the larval density of mosquitoes

Area (1985)	No. of sites examined	No. positive	Results based on dips (Nos.)	Average larval density of positive sites									
				Before cleaning margins					24 hrs. after cleaning margins				
				I	II	III	IV	Total	I	II	III	IV	Total
A. Experimental													
January	48	28	133	2.36	0.79	0.23	0.06	3.43	1.18	0.42	0.10	0.09	1.79
February	37	17	85	1.34	0.29	0.18	0	1.81	0.44	0.27	0	0	0.71
September	66	41	213	9.76	3.58	1.15	0.40	14.89	2.87	0.82	0.43	0.12	4.24
B. Control													
January	23	22	117	3.35	4.11	3.27	1.90	12.63	No change was observed in larval density				
February	14	13	65	6.9	17.63	5.84	2.94	33.32					
September	20	20	83	43.0	32.8	23.21	7.49	106.50					

The production of edible fishes with indigenous larvivorous fishes has motivated the village communities and for the first time composite culture is being practised on a large-scale to control mosquito breeding and improve the village economy. Eight village ponds were selected for food fish culture out of which four ponds had to be abandoned due to drought conditions and large-scale poaching. Remaining four ponds yielded about 10 tons of food fish worth approximately Rs. 1 lakh.

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Small-scale Field Trials with Polystyrene beads for the Control of Mosquito Breeding

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Wells and overhead tanks are the principal sources of mosquito breeding in urban and semi-urban situations. In villages around Delhi, wells are the major sites for mosquito breeding. Most of the wells are unused and abandoned. *Culex quinquefasciatus* is the predominant species associated with well breeding. Other species found breeding in wells were the members of *C. vishnui* group, *Anopheles stephensi* and *A. culicifacies*. In urban situations, overhead tanks are of considerable importance as far as mosquito breeding is concerned. In Delhi city almost every locality has an innumerable number of overhead tanks and the mosquitoes found in association with overhead tank breeding are the vectors of urban malaria, *A. stephensi* and dengue haemorrhagic fever, *Aedes aegypti*.

In an effort to find a convenient approach for the control of mosquito breeding in unused wells and overhead tanks, the effectiveness of Expanded Polystyrene beads (EPS) was evaluated in Delhi and its neighbourhood. The results of the observations made between February 1985 and February 1986 are summarised in this communication.

Well surveys were undertaken in South Delhi (Basantpur area) and West Delhi (Gommanahera and Pindiwala Khurd areas) in January 1985. All wells found with mosquito breeding were numbered. The population of immatures in the wells was sampled using a galvanized bucket (5 litre capacity). A total of 5 dips were taken from each well. The anophelines and culicines were then separated and counted instarwise in enamel trays. The number of pupae collected were also recorded. Polystyrene beads were then introduced with the help of a bucket (16 litre capacity) and allowed to form a thick layer. Generally two buckets of beads (about 650 to 700 gms) were introduced into each well of about 1.5 m diameter and in bigger wells 2.5 to 3 buckets of beads (about 800 to 900 gms) were introduced.

The overhead tanks located in Ayurvigyan Nagar, R.K. Puram (Sector 9), INA Colony and Pushpa Vihar areas were surveyed during June/July 1985 and numbered. Thereafter, the entrance of the ingoing pipe was covered by a small piece of steel mesh to prevent the entry of beads into the pipe line. About 200 gms of polystyrene beads were introduced into each overhead tank.

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Post-treatment observations in wells were carried out at weekly intervals. After taking one sample, the beads drawn along with the bucket were removed with the help of a metal strainer and transferred to an enamel tray and the larvae (instarwise), and pupae were counted. The larvae (instarwise) and pupae which were found dead were also counted and recorded separately. The beads collected from all the five samples were returned to the well.

The post-treatment observations in overhead tanks were also carried out at weekly intervals. The breeding was checked with the help of an aluminium spoon (60 ml capacity) or an enamel bowl (150 ml capacity). Generally three dips were taken. The contents were transferred to an enamel tray, beads separated carefully and then checked for the presence of immatures.

The EPS beads were introduced into 42 wells of which 25 were found breeding exclusively culicines and the remaining 17 wells had mixed breeding of anophelines and culicines at the time of application. The EPS beads were introduced into eight wells each during February 1985 first and second fortnights respectively, six and three wells in March first and second fortnights respectively, nine wells in July second fortnight and five and three wells during the first and second fortnights of August respectively. A total of six wells served as control. The post-treatment observations were continued for a period of 46 weeks in wells treated during the first and second fortnights of February 1985; for 42 weeks in wells treated during the first and second fortnights of March; for 26 weeks in wells treated in July (second fortnight) and for 22 weeks in wells treated during the first and second fortnights of August 1985. However, in the presentation of post-treatment data, the results of weekly collections have been computed and the monthly average number of immatures per dip sample with range for the entire observation period from February 1985 to February 1986 have been given in Table 1 with density of larvae and pupae recorded in the control group of wells.

EPS beads were introduced into a total of 879 overhead tanks in Ayurvigyan Nagar, R.K. Puram and INA Colony. Pushpa Vihar with 476 overhead tanks was retained as control. The results of overhead tank survey are furnished in Table 2.

There are inherent difficulties associated in the effective control of mosquito breeding in wells. While a larvicide requires weekly application, larviciding is a difficult operation in wells because of long distances between the wells and difficulties in reaching them during the rainy season. The present study on the application of EPS beads has shown that there was a drastic decline in the density of culicine larvae and pupae in the successive weeks after treatment. Further, the EPS beads suppressed adult emergence as seen by considerable mortality of pupae and emerged adults. In case of anophelines, breeding was detected in 6 of the 8 wells treated in February 1985 and one of the 3 wells treated in March 1985. Following application of beads, the anopheline breeding was found to continue for a period of one to three weeks except in two wells where the breeding was recorded for a period of 19 to 22 weeks after application. In all these wells only the early instars were encountered. Fourth instar larvae could be detected during 7 out of 17 weekly observations. However, no pupae could be detected during the entire period of observation. Based on laboratory studies (Sharma, 1984) it was observed that application of EPS beads at the rate of 1.0 gm/m^2 produced high larval and pupal mortality in *Cx. quinquefasciatus*, *A. culicifacies* and *A. stephensi*. In a field study, Sharma *et al.* (1985) found that EPS beads were effective in the control of mosquito breeding in biogas plants and wells in Nadiad taluka, Kheda district, Gujarat. The results of the present study support the observations of the above authors. The method has several advantages, a) it

Table 1. Effect of polystyrene beads on mosquito control in wells

	Feb 1985	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Jan 1986	Feb
		Months—post treatment											
February 1985 study	Pre-treat-ment	Post-treat-ment											
Number of collections	16	65	66	60	54	51	61	60	44	21	14	40	16
Average No. of immatures													
I-III	458.0	51.3	28.0	17.6	0.025	0	2.5	0.02	0	2.6	2.67	20.6	9.05
Range	0 - 9151	0-1057	0-1573	0-1246	0-2	0	0-353	0-6		0-225	0-626	0-833	0-517
IV	38.0	5.2	0.445	0.44	0	0	0.06	0.006	0	0.095	0.143	0.73	0
Range	18-587	0-344	0-71	0-523	0		0-11	0-1		0-10	0-10	0-89	
Pupae	7.5	0.09	0	0.002	0	0	0	0	0	0	0	0	0
Range	1-267	0-10	0	0	0								
March 1985 treatment		Pre-treat-ment											
Number of collections		9	35	42	36	36	40	37	20	18	12	26	11
Average number of immatures													
I-III	—	524.2	32.2	1.7	0.07	0.08	0	0.04	0	3.8	9.9	357.3	6.3
Range	—	306-7632	0-1801	0-158	0-3	0-15		0-7		0-148	0-453	0-920	0-343
IV	—	66.5	0.9	0.02	0	0	0	0	0	1.6	0.006	3.0	0
Range	—	28-1441	0-149	0-3						0-128	0-4	0-285	
Pupae	—	5.2	0.001	0	0	0	0	0	0	0.001	0	0	0
Range	—	0-127	0-1							0-1			

contd.

Table 1. (contd.)

	Months—post treatment												
	Feb 1985	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Jan 1986	Feb
July 1985 Treatment						Pre-treatment	Post-treatment						
No. of collections						9	37	36	25	16	11	21	7
Average number of immatures I–III						64.6	4.2	0	0.1	12.0	9.2	5.3	2.34
Range						0–1362	0–481		0–12	0–874	0–201	0–220	0–82
IV						9.15	0.26	0	0.008	7.0	0	0.03	0
Range						0–215	0–24		0–1	0–55		0–3	
Pupae						1.6	0.005	0	0	0.04	0	0	0
Range						0–35	0–1			0–3			
CONTROL													
No. of collections		21	25	27	26	24	27	21	18	9	8	20	8
Average number of immatures I–III		461.5	664.8	70.0	1.45	37.2	51.5	9.7	6.8	34.0	75.0	190.0	466.5
Range		40–6675	35–13941	0–3140	0–61	0–2346	0–4064	0–384	0–358	0–915	0–2454	0–5815	0–9920
IV		80.0	101.5	17.0	0.4	7.6	6.23	0.83	0.044	0	15.0	119.0	14.0
Range		3–1438	0–1369	0–854	0–38	0–722	0–727	0–43	0–4		0–423	0–477	0–196
Pupae		11.3	9.2	3.0	0.12	3.0	2.0	0.2	0.03	0	2.5	2.25	2.4
Range		0–269	0–275	0–145	0–11	0–303	0–188	0–18	0–3		0–73	0–81	0–55

Table 2. Efficacy of EPS beads in overhead tanks

Area		Ayurvigyan Nagar	R K Puram	INA Colony	Pushpa Vihar (Control)
Number of tanks treated		317	172	276	476
July 1985 Number of tanks sampled/positive					
	Week I	0			
	II	0			
	III	72/1			48/7
	IV	72/0	140/3		88/12
August					
	Week I	60/3			
	II				96/4
	III	161/2	52/3		80/6
	IV		143/0		80/0
September					
	Week I	86/0		80/4	331/25
	II	60/0		247/10	96/12
	III	116/0	116/1	125/8	65/19
	IV	141/0	96/2	—	—
October					
	Week I	157/2	172/0	144/1	249/30
	II	68/1	167/2	251/1	414/14
	III	157/0	201/1	280/3	463/7
	IV	223/0	199/1	249/4	465/7
November					
	Week I	286/3	92/0	—	64/1
	II	186/0	—	146/4	318/3
	III	185/0	37/0	270/2	472/7
	IV	—	172/0	276/0	—
December					
	Week I	281/0	—	80/0	97/1
	II	68/0	172/0	—	379/1
	III	—	—	90/0	—
	IV	317/0	172/0	199/0	227/0
January 1986					
	Week I	317/0	—	80/0	265/0
	II	—	172/0	—	211/0
	III	317/0	—	90/0	476/01
	IV	—	172/0	199/0	201/0

Note: In a part of Pushpa Vihar, the beads were constantly being removed as the residents were in the habit of drawing water directly from the overhead tanks. In view of this the entire Pushpa Vihar area was taken as control although the area was treated in the beginning.

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13

Field Trials on the Application of Expanded Polystyrene (EPS) Beads in Mosquito Control

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In laboratory experiments expanded polystyrene (EPS) beads were found very effective in the control of mosquito breeding and they prevented gravid females from laying eggs on the EPS treated water surface (Reiter, 1978; Sharma, 1984). This is a report of the results of preliminary field trials on the control of mosquito breeding in their natural habitats using EPS beads.

Trials were carried out in Nadiad taluka villages, district Kheda, Gujarat. The following sites were selected: (i) a biogas plant, in the slurry around the drum there was heavy breeding of *Culex quinquefasciatus* mosquitoes, (ii) three abandoned wells in which there was heavy breeding of *Culex* sp. mosquitoes, and (iii) two septic tanks in which there was heavy breeding of *Culex* mosquitoes. Before the start of the experiment, anti-malaria staff of the Municipal department treated the septic tanks with larvicidal oil (MLO). All immature stages of mosquitoes died. The EPS beads were applied 1 week after MLO treatment to study whether the septic tanks would become positive for mosquito breeding in presence of EPS beads. No MLO was applied to the slurry of biogas plant and the wells.

EPS beads were weighed and applied manually by hand at the rate of 50gm/1000cm^2 in the biogas plant (5 to 6 layers of about 2.6 cm thickness), 20 and 85gm/1000cm^2 (i.e., 2 to 3 layers of 1.0 cm and 9 to 10 layers of 4.4 cm thickness) in wells and 70gm/1000cm^2 in septic tanks (6 to 7 layers of 3.6 cm thickness). The density of immatures was measured in the biogas plant and septic tanks by a 9.5 cm diameter dipper and in wells by a 25 cm diameter well net by taking an average of 5 samples each time. Observations on the density of immatures were made on day 0 followed by weekly intervals upto six weeks.

Results in biogas plant and wells are given in Table 1. Breeding in the slurry of biogas plant and well-I declined gradually and reached zero level in the 4th week in biogas plant and in 5th week in well-I. Whereas in well-II and well-III, larval density reached zero in the second and first week respectively and remained at that level upto the 6th week post-treatment period, it may be noted that breeding, continued upto four and five weeks post-treatment in slurry and in one of the wells. This was unusual as the breeding generally terminates in the first one or two

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Table 1. Impact of EPS beads on the control of mosquito breeding

Observation Interval (one week)	Density of Immatures											
	Biogas plant			Well I			Well II			Well III		
	IV instar	Pupae	Larval density	IV instar	Pupae	Larval density	IV instar	Pupae	Larval density	IV instar	Pupae	Larval density
Day 0	14.4	4.8	65.0	Very high density			2.5	0	239.5	7.5	0	31
Week I	31.0	5.0	56.6	Very high density			5	0	14	0	0	0
Week II	25.2	9.2	25.2	11.0	0	334.5	0	0	0	0	0	0
Week III	5.6	2.0	5.6	4.5	0	46	0	0	0	0	0	0
Week IV	0	0	0	6.5	0	15.5	0	0	0	0	0	0
Week V	0	0	0	0	0	0	0	0	0	0	0	0
Week VI	0	0	0	0	0	0	0	0	0	0	0	0

Notes: 1. Rate of application of EPS beads was 50gm/1000cm^2 (i.e., 5 to 6 layers of 2.6 cm thickness) in biogas plant, 85gm/1000cm^2 (i.e., 9 to 10 layers of 4.4 cm thickness) in well-I and III, and 20gm 1000cm^2 (i.e., 2 to 3 layers of 1.0 cm thickness) in well-II.

2. Larval density includes the density of I, II, III and IV instars.

weeks. The beads on slurry develop the tendency to stick together and these were being disturbed by children. As a result breeding persisted for a long time, however, educating the children helped in keeping the layer intact on the slurry and consequently the breeding was terminated. In the case of well-I, some floating objects and a dead dog created a few spots where mosquito breeding persisted. In other wells there was no such disturbance. In the two septic tanks treated with EPS beads one week after the application of MLO, no egg rafts were laid by the mosquitoes. These septic tanks remained negative for mosquito breeding and for egg rafts throughout the six week period of observation.

Wells are the main source of mosquito production in many parts of India. In Delhi rural areas, profuse breeding of *Culex quinquefasciatus* occurs in wells while occasionally *Anopheles culicifacies* and *A.stephensi* are also encountered breeding in wells (Sharma, 1985; Rao, 1984). In other parts of the country such as in Salem and Hyderabad *A.stephensi* breeds mainly in wells and maintains malaria transmission throughout the year (Seetharaman *et al.*, 1975; Batra and Reuben, 1979). Since EPS beads are safe and one application lasts for a very long time, application of EPS beads in wells can greatly reduce mosquito breeding in wells and, it is hoped, would also reduce or eliminate disease transmission. Similar application of EPS beads in septic tanks can eliminate an important source of mosquito breeding on a semi-permanent to permanent basis. Recently the Government of India has placed considerable importance on alternative energy sources, and installation of biogas plants is one of the major areas receiving emphasis by the Department of Non-conventional Energy Sources. However, biogas plants are becoming another source of mosquito production in rural areas because the slurry of these plants supports heavy breeding of *Culex quinquefasciatus* which are vectors of filariasis and the major nuisance mosquito. The application of EPS beads on slurry of the biogas plants would eliminate this important source of mosquito production, thus improving the environment and reducing disease transmission. In a recent study, Curtis and Minjas (1985) have shown that the application of beads in soakage pits and pit latrines is an effective method of mosquito control.

In view of the usefulness of EPS beads in the control of mosquito breeding, more trials and integration of beads in the non-insecticidal methods of vector control are envisaged in the near future.

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GUIDELINES FOR PREVENTION OF MALARIA AND JAPANESE ENCEPHALITIS IN RIVERY VALLEY PROJECTS*

Impact of engineering, agronomy and water management practices on disease vectors, transmitting Malaria & Japanese Encephalitis in India

Irrigated areas in India are increasing with the increased demand for agricultural production. For example rice fields increased from 29.8 million hectare in 1951-52 to 41 million hectare in 1983-84 of which about 17.2 millions hectare are irrigated. Of the total irrigated areas about 39 percent is irrigated by canals, 8.8 percent by tanks, 24.9 percent by tubewells, 20.7 percent by other wells and 6.5 percent by other sources.

In India among the vector borne diseases, Malaria and Japanese Encephalitis are of prime importance associated with irrigation potential resulting from development of River Valley Projects. Literature is replete with reports of increased incidence of malaria with the introduction of irrigation system. Malaria endemicity and increased incidence of malaria deaths in Pattukottai regions near Madras and Mandya District in Karnataka due to introduction of Cauvery - Mettur irrigation project in 1934 and Visvesvarya canal respectively are well known. In the recent times high incidence of malaria associated with Upper Krishna River Valley Project in Karnataka has raised a controversy at International level regarding funding of the project by World Bank.

Japanese Encephalitis is another important vector borne disease which has become endemic in areas of intense rice cultivation. In India, between 1978 and 1987, 39,149 cases with 14,246 deaths - a case fatality rate of 36 per cent was recorded.

Economic losses as a result of high morbidity and mortality have crippling effect on the economy of the country, besides individual sufferings. Therefore, introduction of river valley projects, without adequate safeguards against these vector borne disease could become a harbinger of disaster rather than ushering in an era of prosperity.

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BUDGET FOR HEALTH SECTOR:

It has been observed that practically all projects whether in public or private sector earmark some percentage of the estimated cost of the project to meet the requirements of health sector but all these financial commitments are utilised towards CURATIVE aspects of the medicare and not on PREVENTIVE aspect while much of the problems are preventible and recurring cost avoidable, besides saving of productive man hours loss/ suffering.

PLANNING FOR PREVENTIVE MEASURES:

It is therefore, imperative that a carefully planned survey to determine the adverse health impacts should go hand in hand with engineering surveys. The findings of such a survey should receive full consideration before finalizing each project which includes not only the impoundment area but also the distribution system and necessary provision should be made for implementing the recommendations in the estimate of the projects.

HEALTH SURVEY TEAM:

Health survey teams should comprise of public health experts viz. Malariologist, Medical Entomologist, Public Health Engineers and Agricultural Engineers. Services of these experts can be provided/loaned by Public Health/Agricultural Institution of the State and Central Government.

ENGINEERING MEASURES FOR PREVENTION OF MALARIA AND JAPANESE ENCEPHALITIS:

Engineering measures for prevention of malaria and Japanese encephalitis should be incorporated as built in process of the project and as such should receive consideration under the following three stages.

i) Planning and Design stage
ii) Construction stage and
iii) Maintaince stage

A. PLANNING AND DESIGN STAGE:

a) Selection of impoundment area

The final selection of impoundment areas which involves a considerable amount of initial engineering surveys work should

Contd....3

invariably be followed by malaria survey. Such surveys may also include an investigation as to whether a provision could be incorporated for malaria surcharge in the dam/barrage height. The need for an induced periodic water level fluctuation in constant level pools, appurtenant to the main impoundments (i.e. barrage ponds, and stilling basins) may not be a flat requirement, but rather a possible need to be considered in the overall water management plan so as to avoid loss of water in carrying out this function.

b) <u>The Dam Site:</u>

Depending upon the topography of the country, two main problems arise as a result of impoundment: trees and vegetation to be submerged and villages in the submersion area.

i) <u>Trees and Vegetation:</u>

The area to be submerged may be inhabited and clothed with forest or scrub jungle or be barren with no mentionable vegetation.

Clearing the forest and scrub jungle preliminary to impoundage is necessary and/or desirable from the point of view of the following:-

a) Reduction of mosquito breeding potential
b) Safety of the dam and its appurtenances,
c) Safety of navigation, fish culture, fishing and other recreational vocations (boating etc.)
d) Avoiding the development of foul smell due to rotting vegetation and discolouration of water.

ii) <u>Siting of villages in the submersion Areas:</u>

Adequate arrangements will have to be made to ensure that the villages in the submersion area are shifted well before actual impoundage begins. It is here, that a survey furnishing information in regard to malaria hazards in the proposed rehabilitation area, will be very necessary. Preparation and maintenance of the shore line and zone of fluctuation will have to be provided for both in impoundments and barrage ponds. It is desirable that the rehabilitated villages should not be within one and half KM of the highest pool level of the reservoirs. As health of the people in the rehabilitation villages and those along the shore line will be the direct responsibility of the project authorities, provision for protection against malaria will be most vital.

iii) Preparation of fluctuation Zone:

In every reservoir the zone of normal fluctuation will require close attention. Ordinarily, a reservoir fills during rains (4 to 5 months) and a draw down period of 7 to 8 months exposes several small collections of water and seepages in the zone of fluctuation where the two important vectors of malaria in India, viz., A.culicifacies and A.fluviatilis may breed luxuriantly. These collections of water will have to be eliminated along the periphery of the reservoir in the zone of fluctuation. Close vigilance will be necessary to watch all such pockets which may breed mosquitoes. Preparation of the zone of fluctuation should be effected once during pre-impoundment and once again immediately after the first drawdown when these collections and seepages will be more apparent. Yearly review will also be necessary.

iv) Seepage potential of Earthern Dam:

Earthern irrigation dams/embankments are prone to seepage and its trapping becomes essential for safety of the dam. However its disposal never attracts the attention of the irrigation engineers and this water is let loose and results in creation of marshes and swamps and thus become breeding grounds of vector mosquitos and the villages in the command areas show high incidence of malaria. Hence, appropriate drainage schemes should be always developed and incorporated as a part of the project to prevent malaria.

v) Designing of Discharge gate:

This requires attention at two points; exit gate and further down stream.

a) Exit gate:

The pitched/concerete areas against the discharge gate and the speed breaker should be sufficient in number so that it should arrest the speed of the water and should not create pond immediately after the pitched area by soil erosion downstream.

b) Down Stream:

The discharge of seepage water for Dam in non-irrigation season/ dry season often results in formation of pools in the river belt which prolificly breeds A.culicifacies. therefore, it becomes necessary to make provision for flushing flows to combat this problem.

At dam site, where the bed is rockey a "cunette" can be 'build to stream line the flow of water' and prevent stagnation.

vi) Canal systems:

Untidy irrigation system is known to set in extensive water logging of the areas which not only render the fertile land into waste land, but also stagnates large bodies of water conducive for breeding of A.culicifacies the vector of malaria. Therefore, laying of canal system needs special attention and incorporation of engineering design so that the irrigation becomes tidy. The following points need special attention.

1. Alignment of canal/distributaries should provide adequate drainage cuts to permit natural drainage of the area and to prevent water logging.

2. The canal system should provide very tidy irrigation by providing infrastructure which would not lend itself to leakages. Modern technology of lining the canal system with low density polythene sheet may be considered to prevent not only the water loss but also the seepage of water.

3. The canal should be designed straigt as far as possible avoiding acute curves and with proper gradation for ensuring proper water velocities.

4. The burrow-pits for the construction of canal embankments should be avoided as far as possible and may be relied on modern gadgets to bring earthwork from elevated lands. Should it become necessary to dig burrow-pits they should be properly drained into natural drainage system.

5. Alignment of the canal in areas with high potential for water logging should be avoided.

6. Already water logged areas should be drained.

7. Wherever a new canal is being dug to replace the old canal system (as in the case of Upper Ganga canal project) the old canal system should properly be dressed so that does not retain rain water and provide linear breeding places for mosquito.

vii) Drainage system of excessive water:

Whereas there exist provision for net work of irrigation canal to take water to the fields for irrigation there does not exist any provision to drain the excess water from the fields or seepage water being impounded in the adjoining low lying areas along with fields. Therefore, there is a need to provide an adequate drainage system for draining of the excessive water.

B. CONSTRUCTION STAGE:

This stage has three phases:

- Construction of the dam,
- reservoir preparations, and
- excavation of the distribution system.

1) Dam construction:

a) Elevated and well drained sites should be selected for location of several temporary labour camps and permanent colonies for the maintainence establishment.

b) Jungle clearing around the labour camps should be undertaken to expose the seepages/water collection for treatment of larvicides.

c) Antimalaria drains should be constructed for drainage of the dam site.

d) An organisation for carrying out recurrent measures for any malaria hazard in different camps both for superior staff and labour must be provided.

e) There should be a close liaison between the engineering department and the malaria organisations.

2) Reservoir Preparation:

i) Arrangement should be made for exploitation of valuable timber.

ii) Removal of all trees, bushes and other vegetation likely to emerge at maximum draw down level of the reservoir. It is desirable that all trees within the submersive areas and about 5 feet or more depending upon local conditions, land word from the highest pool level should be cut but never uprooted. The trees should be cut as close as possible to the ground level allowing stumps of not more than six inches.

iii) Straighting of margins through cutting, deepening and filling of reservoir edge.

iv) Filling of natural or man made depression in the vicinity of reservoir or draining of these depressions by ditches leading to the reservoir.

v) Provision of paths and other means of access to the reservoir edge for vegetation clearance and for pesticide application if need be.

vi) All protective works provided for the prevention of seepages should be executed and it should be made obligatory that the layout of borrow-pits be made a planned basis to permit efficient drainage during the post construction operations.

C. MAINTENANCE STAGE:

If all the requirements indicated by a previous detailed survey of the area are incorporated in the project estimates and the works are actually executed, it is expected that there will be little or no malaria immediately following the channel system being put into service. Malaria that could be attributable to the project cannot be kept down unless an adequate provision for a regular maintenance is provided. Where necessary for taking care of any residual malaria, recurrent measures should be the responsibility of the Malaria Organisation of the project or the State concerned.

Specification for Civil Works:

Specification for executing of civil works connected with River Valley Project are included in "Health Bull. No.32- "Malaria Incidential to Engineering Constructions" NMEP 22-Sham Nath Marg, Delhi-110054.

Procedure for carrying survey works:

The procedure adopted by the earstwhile Mysore State now Karnataka is cited below as an example :

River valley projects are prepared by the Public Works Department, major ones by the project division attached to the Chief Engineer and minor schemes by project sub-divisions attached to the Circle Superintending Engineers. Simultaneously with the according of administrative sanction to a project a development committee consisting of the Chief Engineer and all the heads of developments as member is also constituted by the Government for all major projects. Working sub-committees are also constituted to carry out detailed surveys, coordination etc. The number of these sub-committee are considered by the main committee and their recommendations are forwarded to the different departmental heads who are responsible for implementing them, after getting competent sanction. The cost of all engineering works are debited to the capital cost of the project. One or more of such sub-committees are responsible for carrying out health surveys mainly with a view to suggest measures for prevention of malaria developing as a health problem. Such a committee consists of representatives of the Health, Engineering, Irrigation and Revenue Departments. They jointly visit the area included in the project list and put up detailed proposals regarding:

i. alignment of minor channels:
ii. protective works necessary for any villages within the flight range of local vector species;
iii. drainage and other protective works necessary within such a range as in (ii) above;

iv. treatment for tanks or other collections of water;

v. crop planning, with suggestions for the types of crops to be grown; and

vi. other rural amenities required, like drinking water wells, schools, culverts, crossings across channels etc.

The above indicated procedure had been approved by Government and such detailed surveys have been carried out in respect of the following projects:-

1. Visweswariah canal area,
2. Marcuhalli project
3. Tunga project
4. Nugu project, and
5. Lakkavalli project

ANTI MALARIA ORGANISATION

Preliminary Stage(Planning and Design)

1.	Malariologist	- 1	(Status of an Executive Engineer)
2.	Medical Entomologist	- 1	(do)
3.	Malaria Engineer	- 1	(do)
4.	Lab. Technicians	- 2	
5.	Insect Collectors	- 4	

(Technical personnel may be supplied or trained at the National Malaria Eradication Programme, 22-Sham Nath Marg, Delhi.

Construction Stage(Ave.colony - 10,000 people)

1.	Malaria Officer	- 1
2.	Malaria Engineer - Technical Adviser (Project)	
3.	Medical Entomologist	- 1
4.	Malaria Inspector	- 1
5.	Superior Field Workers	- 2
6.	Field Workers	- 10
7.	Lab. Technicians	- 1
8.	Insect Collector	- 1

Insecticides
Larvicides
Equipment

Maintenance Stage

I. Camp and Reservoir (Establishment vide construction stage (to be continued with suitable modification.

II. * Area under irrigation

(a) Staff

Malaria Officer (Entomologist)	- 1	
Malaria Inspectors	- 8	
Superior Field Workers	- 4 (	12 months
Field Workers	- 12(	
Superior Field Workers	- 20 (	5 months
Field Workers	- 110(	

(b) Malaria Engineer
with necessary subordinate staff for maintenance of anti-malaria engineering works.

(c) Contingencies
Transport
Motor boats

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* This establishment is what is required for protecting one million people. Suitable adjustment is to be made where there is already an existing organisation e.g., National Malaria Control units working in the different States

APPENDIX 1

TECHNIQUE OF SURFACE OR OPEN DRAINAGE

- Mosquito control ditches should be designed to drain an area in three to four days, before larvae and pupae have had time to develop into adult mosquitos.

- Drainage lines should be as straight as possible to prevent erosion and to shorten the length of ditches.

- As a general rule, open drains should be narrow and deep rather than broad and shallow.

- The required depth of the drainage channel is usually determined by the level of the outlet and, to a lesser extent, by the slope of the land.

- The nature of the soil also affects the depth and number of drains needed to keep the groundwater level at a safe distance from the surface. Where the ground consists of clay, deepening a drain may not increase the area of its influence to any measurable extent, because the friction exercised by the fine soil particles in clay and their powerful capillary action may prevent the water from ever reaching the drainage zone. In such soils a large number of shallow drains may be needed first, until the character of the soil improves. Fewer drainage channels will be required later, and the functionless drains can then be filled in and the remaining drains deepened with good effect.

- It is desirable to give a fall of at least 75 cm to the kilometre (1 in 1300), but a fall of 20 cm to the kilometre (1 in 5000) may be sufficient if the ground is so flat as to prevent a steeper gradient.

- The velocity of water should be kept below a safe limit in order to reduce the erosive power or the cutting capacity. This limit ranges from 30 cm per second in fine sand to 90 cm per second in stiff clay.

- The banks should be kept clear of vegetation and sloped to an angle of about 45 degrees (i.e. 1 in 1). For example, an open drain averaging 30 cm in width at the bottom and 120 cm in depth, should be about 3 m wide at the top. In the coarser textured soils a 2 to 1 slope may be advisable, and very sandy soils may require slopes of 3 to 1.

- The bottom of narrow drains should be rounded and not flat or V shaped, but in broad drains a shallow V is preferable to a flat bottom.

- The drain is usually lined with concrete, brick, stone, etc., or may be simply an earth drain. It is not always necessary to line the entire depth of the drain, the lining of the bottom and sides up to 10 cm above the normal water line being sufficient. For this purpose a pre-cast concrete invert can be used.

- The spoil banks of a ditch should be moved back from the edge so as to leave a "berm" about as wide as the ditch is deep, so that rainfall will not cause washing of the spoil back into the ditch nor the weight of the spoil cause caving of the supporting bank. Alternatively, the spoil may be spread over a wider area to reduce its height and the corresponding pressure on the supporting ditch bank; in this case, the wider spoil bank should be graded so that rain which may fall upon it will run off away from rather than toward the excavation. Smoothing the top of the soil bank while the recently excavated earth is still soft involves only a little extra labour, and may greatly facilitate any subsequent inspection or spraying of the ditch since the inspectors or spraymen can walk easily and quickly down the spoil bank instead of stumbling along a rough, overgrown unfinished bank.

Appendix 1

- The excavation for drainage should start at the outfall end.

- The main drain should be constructed first, and the tributary afterwards.

- Tributaries should enter at an acute angle or curve where possible, and not at right angles, in order to lessen the deposition of silt and debris at the point of the junction.

- At the point of junction with a side channel, the opposite side of the drain should be strengthened and raised to prevent overflow.

- In places where drain has to pass beneath a road by means of a culvert, the grade of the drain should be increased to prevent the accumulation of silt or debris. The bottom of the culvert should be lined with stone or concrete.

- In the case of foothill seepages, the best method is to construct a system of contour drains, at right angles to the direction of flow, to intercept the seepage above at the point at which it arises (intercepting drains).

- The necessity for repeated cleaning of open earth drains makes their upkeep costly. Lined drains last longer and are more easily cleaned, but these too require frequent inspection and their cost of maintenance is by no means negligible.

APPENDIX 2

TECHNIQUE OF SUBSOIL OR UNDERGROUND DRAINAGE

- Subsoil drainage is a very effective way of dealing with mosquito breeding, since by its means all water is expelled underground, so that mosquitos have no access to it. Its initial costs are high and, besides, it is a method which requires very considerable technical knowledge. But it is frequently in the long run the least expensive form of drainage when intelligently applied.

- A subsoil or under-drain is a ditch in the bottom of which are placed subsoil pipes (or even, on occasions, brushwood, bamboos or stone) to provide an underground channel through which the water may run, the ditch being then filled in with earth to maintain the continuity of the surface.

- Subsoil drains are naturally used where conditions demand the placing of drains at small intervals, since their application saves in upkeep and supervision; in the case of many forms of agriculture, their use prevents the loss of cultivable ground.

- The use of subsoil pipes less than 10 cm internal diameter is not advised, as it is found that smaller pipes are liable to become choked.

- The standard length is 30 cm, but pipes of greater length are manufactured in the case of pipes of a diameter of more than 20 cm.

- The pipes should, as a rule, be laid at a depth of not less than 1.2 m. In general, the steeper the slope the greater should be the depth.

- The bottom of the trench on which the pipe is laid must be evenly graded and should be as straight as conditions permit. The pipes are placed as close together as possible and are kept in good alignment by means of small stones.

- The pipes when laid in the trench ought always to be covered over with palm leaves or with long grass or any other material which will aid in preventing silt entering into pipes from above. For this purpose also, clay or rough canvas may be used to cover the top and sides of the open joints between the pipes. This work complete, the pipes are then covered with earth.

- Trees should be removed from the vicinity of subsoil drains as their roots may grow into and choke the pipes. The usual distance required for such clearing extends to 12 m or more from the pipeline.

- Socketed drain pipes or collars are found useful in making joints watertight when the drains are carried near trees and hedges which cannot be removed. In such cases the junction is tightly sealed with cement. In this way the rootlets of trees may be prevented from gaining access into the pipe. Another alternative method: the pipes may be laid in gravel, gas tar being poured over the joints to keep the roots away.

- Every subsoil drainage scheme should be planned with as few outlets as possible, constructed of either concrete or bricks, and discharging as a rule into streams or lakes or ditches at a higher level.

- Never cover subsoil pipes directly with stones as there is a danger of cracking or breaking the pipes.

- In very soft and wet soil, a bottom layer of cinders or crushed stones may be laid as a foundation for the subsoil pipes.

Appendix 2

- Pipes to be laid from downstream upwards, always guarding against blockage at the upper end.

- Subsoil lines are spaced from 10 to 30 m apart, closer in heavy than in light soil.

- Subsoil lines should be as straight as possible and any change in direction should be by means of long and easy curves.

- Changes of gradient should be avoided wherever possible, especially if the change is from a steep gradient to a flat one, as a sudden flattening of the grade causes silt deposition in the flat portion. The remedy is to construct a silt chamber at that point.

- To lower subsoil water, a gradient of at least 25 cm per 100 m is usually required.

- In sandy soil, a gradient as steep as 1:100 for 10-cm pipe and, in clay soil, 1:1500 also for 10-cm pipe; and proportionately less for large-size pipes is better.

- Subsoil pipes should be at least 1.2 m deep, or better still up to 1.8 m deep. In clay soil 60 cm is better than 1.2 m and, if the normal water-table is near the surface, a depth of 2 m is better.

APPENDIX 3

CONSTRUCTION OF AN AUTOMATIC SIPHON AT BOTANICAL GARDEN, PENANG

1. Botanical Garden, located approximately 8 km from George Town, is practically surrounded by hills. A wide ravine divides the area, through which flows the main rocky hill stream together with its smaller branches flowing from the north. The whole area is under antilarval control comprising permanent drainage and weekly larviciding. One of the branch streams, approximately 300 m long, which was under weekly larviciding, was selected for the construction of an automatic siphon.

2. The description given here is non-technical as the construction of this siphon is purely based on field experience and observation. It is intended only to give some practical hints in the method of construction, stage by stage, until it is completed. This construction was actually the result of a combined effort by a health inspector, masons and labourers. Through such effort and direct field participation in the construction, a successfully working automatic siphon has been erected.

3. The decision to construct the siphon was made firstly because of constructional and operational feasibilities. The gradient has to be sufficient and the flow of water continuous throughout the year. Further, with stopping of the weekly larviciding, labour may be deployed to other areas. Furthermore, such a construction can give practical training to many inexperienced masons.

4. From field observations, the velocity of water, the depth and width of the stream should be noted. The upper part of the stream should also be inspected to determine the best possible point where the dam may be erected. The point chosen would be at a slightly higher level which should not only assist to create a strong flush but also to cover a reasonable flushing distance. That part of the stream should be sufficiently wide to accommodate the size of the reservoir with minimum excavation. The bed of the stream should be firm and without any crevices or holes which could form underground outlets.

5. From field studies, it was decided to construct a 25-cm siphon with a 1.35-m high retaining wall. The reservoir would be 8.7 x 4.2 x 1.5 m, with a capacity of 55 m^3. The whole construction was carried out by antimalarial workers, comprising six labourers and three masons.

6. The first stage of construction began soon after the whole site had been cleared. A cement concrete base is first prepared for siting the dam outlet pipe. The cement concrete is then filled in to complete the required length of the basement. From this basement, the retaining wall is built up upwards, stage by stage.

7. The erection of the siphon pipe is the most important part of the whole construction. The siphon tube comprises several pipes joined together. Antilarval subsoil pipes can be used, though not as good as lazed sewer pipes which are comparatively more intact and airtight. Furthermore, sewer pipes are provided with connecting heads which facilitate installation work. Only the best pipes should be selected. This is indicated by a hard ringing sound when the pipes are gently knocked. The sewer pipes used for this siphon are 25 cm in diameter, which is considered appropriate for the size of the reservoir and flow of water.

8. The siphon tube is erected at the centre of the retaining wall. Two bend pipes are first joined together to form the siphon outlet. A space is excavated at the base of the retaining wall where the siphon outlet is properly positioned, at a level with the bed of the flushing drain. From this outlet, pipes are connected and erected vertically and, at the same time, the inlet siphon pipes are also erected. Pure white cement is used to join the pipes. Before these outlet and inlet pipes are connected, the working level and maximum height of the siphon tube has to be determined.

9. The reservoir is then filled up to the maximum level. The height of both the inlet and outlet pipes is then adjusted to a level at which the flow starts to trickle down the outlet pipe. When this level is obtained, then the pipes are fixed into position and connected.

10. In the particular siphon used, three different sizes of air tubes were installed. The air tube should be positioned beside the siphon tube, extending about 30 cm longer than the siphon outlet, rising across the retaining wall and down to a few centimetres above the inlet opening. The connecting air tube is made to extend a few centimetres into the siphon tube.

11. Before the air tube is installed, its correct level must have been determined. The reservoir is again filled up to maximum level. Holding the connecting tube, the horizontal part of the air tube is inclined upward and downward. During the process, a certain level should be obtained at which a hoarse sound is heard within the siphon tube. That level indicates the correct functional level. The process of determining this level can be time-consuming.

12. Having fixed the level of the air tube and the connecting tube effectively sealed, the reservoir is again filled up and the working of the siphon is tested. Once it is in working order, the siphon outlet pipe, the extended dam outlet pipe and the air tube are covered with concrete and levelled about 30 cm above the bed of the flushing drain. The vertical part of the air tube rising across the retaining wall down the inlet siphon tube is also covered with concrete. The stream-bed directly below and adjoining the siphon inlet is deepened to about 30 cm.

13. While the installation of the siphon tube is being carried out, part of the labour force should prepare the concrete wall on both sides of the reservoir. The flushing drain should be straightened to a distance of about 4 m to give the flow an added initial force. Boulders available at the site can be used to construct the walls.

14. The entire work should be completed within two to three months.

15. The flush from this siphon was reasonably strong, lasting about nine minutes and covering an effective distance of some 200 m. This distance was subjected to repeated larval checking and no breeding was detected in the intervening water.

16. For more than three years after it was built, the siphon worked perfectly. The only maintenance work done was repainting of walls and siphon tube.

17. A total of 16 siphons is still functioning in the State of Penang. Their combined flushing distance is more than 3000 m. Considering that these siphons have existed more than 50 years and are still functioning, they have, compared with the cost of larviciding, saved large sums of money on the cost of their construction. Automatic siphons have played an important contributing role in the overall antilarval programme in the State of Penang.

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WORKSHOP FOR ENGINEERS, ARCHITECTS, TOWN PLANNERS AND PUBLIC HEALTH ADMINISTRATION ON PREVENTIVE AND CORRECTIVE ASPECTS OF MOSQUITOGENIC CONDITIONS CREATED AS INCIDENTAL TO ENGINEERING PROJECTS/WORKS.

VENUE : ________________ DATE : / /19

PROFORMA ON THE PARTICIPANT'S OPINION

1. Whether you found the course useful : Yes _______ No _______

2. Which aspects of the course in your opinion need more : Lectures / Field work / Video Film / demonstration / Any other

3. Whether the duration of the course was adequate, if not, kindly suggest the required duration : Yes _______ No _______

4. What level of officers would you recommend for future workshops of this kind : AE ____ EE ____ SE ____

5. What other disciplines, besides engineers should be given this training (list in order of priority) :
   1.
   2.
   3.
   4.
   5.

6. Would you be able to implement or utilize the knowledge gained in your day-to-day work : Yes _______ No _______

7. Would you suggest a capsule course for undergraduates and diploma course for engineering students : Yes _______ No _______

8. Do you feel the need of a policy decision (i) at higher level for implementation of engineering methods in the control of mosquito breeding or (ii) it could be done without any such intervention or direction from above : (i) (ii)

9. Any other suggestion or remarks (Please use reverse side) :

Date : / /19

Name :
Designation :

Note : Please mark cross (X) in the box if you agree.