

ARTICLES

STATUS OF MALARIA ERADICATION IN INDIA—1965¹DONALD R. JOHNSON²

The most dramatic public health effort ever undertaken by man, and the greatest, is the National Malaria Eradication Programme (NMEP) being conducted by the Government of India. This tremendous program encompasses an area of 1,266,900 square miles (3,243,264 square kilometers) with a population now exceeding 475,000,000 persons. The people of India are receiving excellent protection from this once dread disease which did so much to retard the economic and social development of India for centuries. In order to understand and appreciate the outstanding accomplishments of this program, it is necessary to delve into the history of this disease in India, as well as to follow the progress of the campaigns to control and eventually to eradicate malaria.

Prior to World War II, it was estimated that in India there were at least 100,000,000 persons annually who suffered from the disease, with some 1,000,000 deaths. Even more significant than the deaths was the lowered vitality of those afflicted by malaria, thereby causing these individuals to be non-productive and a drain on the economy of the country. The British malariologist Sinton (Anon., 1960) once stated, "The problem of existence in very

many parts of India is the same problem of malaria. There is no aspect of life in this country which is not affected, either directly or indirectly, by this disease. It constitutes one of the most important causes of economic misfortune, engendering poverty, diminishing the quantity and the quality of the food supply, lowering the physical and intellectual standards of the nation, and hampering increased prosperity and economic progress in every way."

When one considers the adverse effect that malaria has had in India, the present advanced state of the eradication program is almost unbelievable. Even 3500 years ago, references were made in the literature of that age to a fever which undoubtedly was malaria. The Atharva Veda around 1500 B.C. even went so far as to classify the periodicity of the fever attacks; i.e., "quotidian, tertian and quartan." The word for mosquito in the Atharva Veda is "makka," which is the same as the word "masaka" found in classical Sanskrit. Interesting references also are found in Marco Polo's writings, which mention the use of mosquito nets in India in the 13th century, A.D.

MALARIA CONTROL EFFORTS. In 1845, a British Army Commission was appointed to investigate the causation of malaria which followed the opening of the Western Jumna Canal. It was at this time that the spleen rate first was utilized as a malariometric index. This was done by Dr. T. E. Dempster, a member of the British Army Commission. Studies of malaria and its transmission were continued for many years in India.

However, it was left to Sir Ronald Ross, working in that country, to prove that malaria is transmitted by mosquitoes. This was demonstrated in studies with

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bird malaria in 1897-1898. In 1899 Ross published his report on these studies, which made it possible to initiate effective malaria control measures eventually leading to the modern malaria eradication program. A malaria commission was appointed in 1899 to investigate the possibilities of malaria control in the Lahore area of what is now Pakistan. This committee concluded that antimosquito measures could not control malaria under the conditions that prevailed in that area. However, in 1908, a devastating malaria epidemic occurred in the Punjab. An Imperial Malaria Conference convened in 1909 in Simla recommended that a permanent organization responsible for research on malaria and its control be set up. As a result, the Central Malaria Bureau was founded in 1909 with Sir Rickard Christophers as its first Director. In 1927, the Central Malaria Bureau became the Malaria Survey of India and the late Brigadier J. A. Sinton was named as Director. He was succeeded by Major General Sir Gordon Covell in 1936. In 1938, the name was changed from the Malaria Survey of India to the Malaria Institute of India, with headquarters in Delhi. The duties of the Director of the Institute at that time included the administration of malaria control activities throughout all of India.

Sir Gordon Covell continued as Director through World War II, and in 1947, Lt. Colonel M. K. Afridi became Director for several months. Independence came to India that same year and Lt. Colonel Jaswant Singh took over as Director, continuing for the next decade. He was succeeded by Dr. B. Ananthaswami Rao who was Director for one year starting in 1957. In 1958 the Government of India, in order to permit the Institute to devote full time to technical support, training, research and independent evaluation as pertains to the malaria program, created a separate full-time Directorate and organization for implementation of a malaria eradication program. Dr. S. P. Ramakrishnan then became Director of the Malaria Institute and Dr. B. A. Rao was appointed Director of

the newly-created National Malaria Eradication Programme. In December 1959, Dr. Rao was followed by Dr. A. P. Ray, who continues as present Director of NMEP.

In 1962, the Malaria Institute became the Central Institute for Communicable Diseases. The program was broadened and in 1963 the Institute was redesignated, and remains, the National Institute of Communicable Diseases (NICD) as described by Ramakrishnan (1963). Although the Institute under Dr. Ramakrishnan and the staff of more than 300 persons now has many responsibilities in the broad field of communicable diseases, malaria studies continue to be the most important segment of its activities.

From 1900 to 1936, the fight against malaria was confined principally to biological control of the mosquito larvae and the use of larvicides. Both oil and paris green were used. Drainage work also was done. From 1936 to 1942, effective control of malaria transmission was attained experimentally by Russell, Knipe and Sitapathy (1943), with the assistance of T. Ramachandra Rao,³ by killing adult mosquitoes in houses with pyrethrum used as a space spray. As a result of the India tests, it was concluded that this method is very effective in reducing malaria transmission but that space spraying would need to be continued year after year. It was believed to be an economically feasible measure in rural South India.

During World War II, DDT was introduced into India. In 1944 and 1945, Senior-White (1945) tested DDT with success against anopheline vectors of malaria, thereby preparing the way for the subsequent eradication effort.

By the beginning of 1953, the Indian Government was spending approximately 15 million rupees (\$3,150,000) per year for malaria control programs that protected about 30 million people. The pro-

³ Personal communication from Paul F. Russell, June 22, 1965.

gram was then designed as part of the First Five-Year Plan to establish 125 malaria control units, each unit protecting approximately 1 million persons. The Government of India was to provide the rupee costs and the United States Government, through its foreign aid program, agreed to furnish DDT, vehicles, drugs, microscopes, and certain other commodities for the program. On December 13, 1952, the Indian Government signed an operational agreement with the United States Government establishing a National Malaria Control Programme. The program actually became functional in April 1953. It developed rapidly, and by 1956-1957, more than 145 million persons were protected from malaria. At that time, the decision was made to change the program from malaria control to malaria eradication. The program was converted to malaria eradication, effective April 1958, with continuing assistance from the United States and the World Health Organization (WHO).

MALARIA ERADICATION. Malaria eradication requires complete elimination of the malaria parasite from the human population. This does not imply mosquito eradication, although the eradication of the parasite is attained principally through destruction of the infected mosquito vector of the parasite, supplemented by the use of drugs to destroy parasite reservoirs. Normally, a malaria eradication campaign passes through four distinct program phases: Preparatory, Attack, Consolidation and Maintenance. Ray (1963) thoroughly described and discussed the entire program, but for this paper the India program phases are summarized briefly below.

1. *Preparatory Phase.* Geographic reconnaissance, malariometric survey, program planning, training, procurement of commodities, and other preparations are accomplished during this phase. In India, this phase was considered to be in effect especially during the years 1953-1958 when the control program was in progress.

2. *Attack Phase.* Normally, this con-

tinues for three or more years, during which time all houses are sprayed with residual insecticide to destroy the infected anopheline mosquitoes. The India program is carried out principally through a DDT residual spray program with an attack phase of 3-5 years spraying of all houses in the areas of risk from malaria. The inside surfaces of the houses are treated two or more times per year with DDT, applied in a 5 percent suspension at a rate of approximately one gram of DDT per square meter per application. Through this method, the six vectors of primary importance (of the total 40 *Anopheles* species known in India), namely, *Anopheles culicifacies*, *A. fluviatilis*, *A. minimus*, *A. philippinensis*, *A. stephensi*, and *A. sundaicus*, are in most instances satisfactorily controlled. The secondary vectors, *A. annularis*, *A. leucophyrus*, and *A. varuna*, which are of local importance in some areas, in most instances also are controlled by this treatment.

During the attack phase, the DDT used principally is a 75 percent water-dispersible powder formulation manufactured in the United States. Supplies from this source are augmented with a 50 percent DDT water-dispersible powder manufactured in India in two factories donated by the United Nations Children's Fund (UNICEF), one located in Delhi, the other in Alwaye, Kerala State. Some locally manufactured 50 percent benzene hexachloride water-dispersible powder containing 6.5 percent gamma isomer is used to supplement DDT in areas where the vector *A. culicifacies* has become resistant to DDT. The benzene hexachloride is used at the rate of 1½ pounds per imperial gallon of water. The sprayers used in the program for all insecticidal spraying are manufactured in India. Both stirrup pumps and hand compression sprayers are available.

The attack phase brings with it problems of special interest to the entomologist. For instance, bedbugs have become a serious nuisance in some of the houses

sprayed with DDT. They have developed a resistance to DDT, and the local residents object to the use of DDT, claiming that the bedbug populations increased to a greater number than was encountered prior to the use of DDT. In some areas DDT resistance in bedbugs has created a serious problem (discussed later) and a 40 percent Diazinon water-dispersible powder is used along with the DDT, which gives control of the bedbugs. Thirty grams of the powder are used per pound of 75 percent DDT and sprayed with the DDT in the infested houses. This, however, is an expensive measure and is avoided wherever possible.

Painting the walls and replastering after certain religious festivals has been another handicap in limited areas, as the effect of the DDT is masked by the paint or plaster. For this reason, the teams in these areas apply the insecticide three or more times per year.

There are special problems with certain vector species. For instance, *A. stephensi*, one of the most difficult of the principal vectors to control, is important particularly as a vector of urban malaria. It is found breeding in wells and cisterns, and at the margins of sluggish streams and pools. In some areas it has developed a resistance to DDT as well as to benzene hexachloride and related compounds. At the present time, therefore, the species is being controlled by the use of larvicides, such as aviation gasoline, lead-free (AGLF), although this increases the cost considerably. Because the AGLF is toxic to the larvae yet evaporates rapidly, it is used to treat wells and cisterns where larvicides normally are objectionable.

In addition to the anti-mosquito measures, the use of drugs against the malaria parasites is an important phase of the program. House visits made during surveillance operations to locate remaining malaria infestations are initiated during the third year of the attack phase. Drugs are administered by the "house visitors" (surveillance agents) to all fever cases.

3. *Consolidation Phase.* This phase

follows withdrawal of routine spraying operations and places principal reliance on the surveillance operation. During the attack phase, residual insecticides in the houses provide a protection against malaria transmission. Before a change can be made to move from the attack to the consolidation phase, epidemiological studies carried on during surveillance activities must confirm the readiness for withdrawal of spraying operations. The consolidation phase usually continues for two or more years before the program is ready to enter into the maintenance phase. If active transmission is taking place, the consolidation phase must be extended. Principal reliance is placed upon drug treatment during the consolidation phase, although focal respraying of areas with positives also is done to prevent reestablishment of malaria. Mass blood smears are taken in these areas where positives occur, and mass radical treatment is ordered when deemed necessary. Intensive epidemiological investigation of all positive cases is made in order to insure that infestations do not become re-established.

Presumptive treatment of suspected cases is given at the time blood smears are collected. A 4-aminoquinoline (either chloroquine, or amodiaquine) at the dosage of 600 milligrams per adult is used. After blood slides have been examined, the house visitor administers radical treatment to persons found positive for malaria. This treatment consists of a combined dosage of 600 milligrams of chloroquine or amodiaquine (Camoquin) and 15 milligrams of 8-aminoquinoline (primaquine) on the first day, followed by 15 milligrams of primaquine daily for four additional days.

According to Ray (1963), the criteria recommended by WHO (1961) Expert Committee on Malaria, Eighth Report, basically are to be followed before the program can pass from the attack phase into the consolidation phase. In India some of the major considerations are as follows:

- a. There must be an almost complete interruption of transmission: if there is any transmission, it must be limited to restricted foci and appropriate remedial measures are to be in effect.
- b. Not more than 0.1 case of malaria per 1000 residents of the unit area (equivalent to 100 cases per 1,000,000 population) per year.
- c. The annual blood examination rate shall be a minimum of 5 percent of the population for formerly hypo-endemic areas and 6 percent minimum for formerly endemic areas, and shall include both types of surveillance smears: active (taken by house visitors) and passive (taken routinely on all fever cases by doctors, hospitals and dispensaries).

4. *Maintenance Phase.* This is the final stage of the program. During this time a special staff no longer is required to maintain the malaria-free condition of the area. The normal health services of the area are expected to assure against the reintroduction of malaria. Obviously, a well-organized health program will be required before the maintenance phase can be effective. Before a unit in the consolidation phase may pass to the maintenance phase, certain criteria must be met, according to instructions from the NMEP Director (Ray, 1964):

- a. The unit must have been in the consolidation phase for at least 2 years and must have had an active surveillance program for 3 years or more.
- b. The entire population of the unit area must have been covered by the surveillance activities.
- c. Active surveillance as well as passive surveillance must be adequately carried out.
- d. Blood slides shall be taken from 10 percent or more of population annually, with not less than one percent of population included monthly throughout the malaria transmission season.
- e. Indigenous cases of malaria shall be

absent from the area for at least 3 years unless unusual circumstances exist, such as a situation where there are extremely few cases of an isolated nature unconnected with any other cases, as determined by thorough epidemiological investigations and by repeated mass blood surveys.

- f. All activities of the unit shall be performed in an outstanding manner. Epidemiological investigations, laboratory services, cross-checking of blood smears, supervision, and special investigations all must be found to be highly satisfactory.

Before any unit can be permitted to pass into the maintenance phase, the general health services of the area should be adequate to perform permanent vigilance activities capable of detecting any recrudescence of malaria. Such vigilance must include rapid detection of any imported or indigenous cases, epidemiological followup, and necessary remedial measures. Blood smears from individuals with fever are to be taken routinely for laboratory examination.

NMEP ORGANIZATION. The National Malaria Eradication Programme, now an administratively separate entity but headquartered with NICD, with Dr. A. P. Ray as its present Director, is a carefully organized campaign which involves all of the more than 475 million persons at risk. The unit plan mentioned above has been an excellent system, which basically operates as follows:

India is divided into six regional malaria offices, each headed by a Deputy Director of NMEP. Each region includes two or three states, and the states in turn are divided into units. On the average, each unit consisted initially of one million population, and although there have been increases in numbers through normal population increment, additional units have not been added to those areas. However, each unit staff is augmented as required by these increases. By 1960, when the eradication program was in its third year, 390 units were in operation. At

present, there are 393.25 units in existence, each with a population of approximately 1.2 million persons. Table 2 shows approximate population per state or territory and indicates the distribution of the units.

A unit is under the supervision of a Unit Officer and an Assistant Unit Officer. Frequently these officers are nonmedical personnel, although they are under the supervision of a Zonal Officer, usually a physician, who is responsible for two to eight units. The state program is under the supervision of the State Malariologist, who is on the staff of the State Health Director. Although the unit is therefore administratively responsible to the state, a major portion of the financing, including insecticides, drugs, vehicles, and a subsidy of 50 percent of costs over and above the cost of malaria control, all are provided by the Government of India. The program is under the technical direction of the NMEP, which is a central government organization.

Each unit is subdivided into four sub-units. This means that initially there were about 250,000 persons per sub-unit. The sub-unit is headed by a Senior Malaria Inspector and a Junior Inspector. Each sub-unit is subdivided into six sectors with an initial population of approximately 40,000 persons each. The sectors are each subdivided into four sections, each with a population of 10,000 persons living in some 2,000 houses. The sectors are under the responsibility of a surveillance inspector, and the sections are under a surveillance worker or house visitor. There are about 50,000 surveillance workers in all of India.

Although the sprayman is a key figure in this program, the surveillance worker or house visitor also is a very important person in the campaign. It is his responsibility to see that malaria actually has been eradicated in his section of 10,000 population. He must personally visit *each* of the 2,000 houses or so in his section *every two weeks*. It has been shown by Ray, Sen Gupta, and Misra (1964) that this schedule during the attack and consolidation phases of the program provides

the necessary safety margins required to locate malaria cases. In the maintenance phase, the schedule of visitations can be extended to four weeks, according to these authors.

The surveillance visits are initiated during the third year of the attack phase and continued during the entire consolidation phase. The surveillance worker must inquire at each household at the time of each visit as to (1) whether there is presently anyone in the house with a fever; (2) whether there have been any fever cases in that household since the last visit of a surveillance worker; (3) whether there are any guests or visitors in the house from other areas who are ill, or might have been ill recently; and, finally (4) whether there has been illness of *any* kind in the persons in the house. Chloroquine tablets are administered to any suspect cases, and a blood slide is made. A visible, dated record of each visit of the surveillance worker is made by filling out a form which is affixed or drawn on the wall of the house, along with the initials of the surveillance worker. His supervisor, the surveillance inspector, maintains a constant check of villages and houses to insure that house visits are being made routinely as required. The sector Surveillance Inspector, the sub-unit Junior Inspector, the Senior Malaria Inspector, the Assistant Unit Officer, the Unit Officer, the State Malariologist, the Zonal Officer, the Regional Deputy Director, and even the Director of NMEP himself all check regularly throughout their respective areas of jurisdiction to insure compliance. This constant checking and rechecking the house visitations is one of the principal reasons for the remarkable success of this program.

Although the majority of the units now are either in the consolidation or the maintenance phases, about 78 units still are in the attack phase. During this phase each standard unit employs 170 laborers and 32 superior field workers for the 5-month spray season each year. These spraymen are temporary employees. Two types of sprayers are used—stirrup pumps and

cylindrical hand compression sprayers. When using the hand stirrup pumps, as is done in the areas of high population density, 5 men manning 2 pumps can spray 90-100 houses daily. On the other hand, 3 men operating 2 hand compression sprayers in operationally difficult areas, where these sprayers are used, can treat 20-60 houses daily.

FUNDING. The cost of the program has been borne principally by the Indian and American Governments. Table 1 gives a breakdown of costs from 1953 to 1965, inclusive. The United States assistance, which has been extended through the Agency for International Development (AID) and its predecessor agencies, now is principally on a loan basis. The United States funds for commodities are expended almost exclusively in the United States and are used to purchase U. S.-produced insecticides, vehicles, laboratory equipment, and drugs. These materials have been shipped to India and constitute the great bulk of the commodities used. At the peak of the attack phase, more than 20,000 tons of 75 percent DDT water-dispersible powder were being shipped annually to India as a gift of the American Government for the spraying operations.

The monetary cost of the malaria eradication program in India has in one way been large; but when compared to the tremendous drain exerted by malaria on the physical vitality of the people and the incalculable economic loss to the nation, the cost has been infinitesimal. During the years from 1953 through 1957, the total cost of control measures is estimated in dollars, or dollar equivalents, to be about \$48,000,000. The eradication campaign for 1958 through 1965 has cost some \$260,000,000, or an average of \$32.5 million for each of the eight years. If an average of 400,000,000 persons were protected each year, the annual cost of eradication to date would be less than \$.09 per person!

INDEPENDENT APPRAISAL TEAMS. In 1960, the International Cooperation Administration (ICA), which was the immediate predecessor agency to AID, assembled a team which was sent to India to review the progress of the NMEP as reported by Pletsch, Gartrell and Hinman (1960). This team made a critical review of the program for the U. S. Government, to determine what had been accomplished to date and what remained to be done. This information was needed as a basis

TABLE 1.—India NMEP: Funding¹ of malaria program (in millions of dollars, or dollar equivalents).

	Control program		Eradication program	
	1953-57	1958-64	1965	
1. Indian Government	\$ 21.0	\$ 23.0	...	
2. Counterpart funds ²	0.0	143.2	\$ 15.4	
3. U. S. grants or loans				
A. Commodities				
a. Development grant funds	20.60	62.4	0.0	
b. Development loan funds	0.0	11.0	4.06	
B. Participant training	0.01	0.08	0.01	
C. U. S. technicians	0.03	0.2	0.04	
D. Other	6.50	0.09	0.03	
Total U. S. grants and loans	27.14	73.77	4.14	
4. UNICEF	0.3	0.0	0.0	
5. WHO	...	3.0	0.24	
Total	\$48.44	\$242.97	\$19.78	

¹ From USAID Mission (New Delhi), Airgram TOAID-A 764, Nov. 20, 1964.

² Provided through U. S. Public Law 480 agreement.

on which the United States could plan its future assistance to the Indian program. This review was followed in 1962, 1963, and 1964 by an appraisal performed by the so-called "Independent Appraisal Teams"—Anon. (1964).

The work of the Independent Appraisal Teams is to make a detailed appraisal, annually, of the results of field work and recommendations concerning advancement of units to the next phase of the program. Following is a description of the methods used, and of the work of the 1965 teams, on which the writer served.

The Government of India organized the effort and carried it out according to its own guidelines. The U. S. Government and the World Health Organization each were requested every year to provide team members. The plan provided for several teams, each of which normally consisted of a State Director of Health Services (or an Armed Services Medical Officer) as Team Leader, provided by the Government of India; a WHO malariologist; a U. S. Government malaria specialist; and a Team Secretary, usually a professional malariologist from the NMEP Directorate, also provided by the Government of India.

In January of 1965, 12 teams of four men each were assembled in Delhi in NMEP headquarters. After a period of briefing, the teams were sent to the states assigned to them. Care was taken to avoid sending Indian members of teams to states with which they had an official connection. For example, an Indian malariologist from northern India might be sent to one of the southern states. This was done in an attempt to eliminate any bias or vested interest that an individual might have. For the same reason, the U. S. Government and WHO personnel, whenever possible, were brought in from outside of India, rather than utilizing personnel already stationed there. The team member most familiar with the operation in the area of assignment normally was the secretary. This arrangement was convenient for the team, for this person handled the many necessary details, including arrangements to produce a report

for each unit visited. Although the secretary helped to obtain information requested by the team, he did not enter into the final decisions made by the team.

During the year prior to the visit of the team, the local unit staff prepared for the assessment. Each unit that had progressed to a certain stage was eligible for consideration for withdrawal from attack phase and projection into consolidation phase. Likewise, units that were already in the consolidation phase eventually were projected for entry into the maintenance phase. The units possibly ready for projection were screened by the State Malariologist, the Regional Deputy Director, and the Office of the Directorate of the NMEP. All units that they considered ready for passage into the next phase were then scheduled for review by the Independent Appraisal Teams.

When a team went to an assigned state to make an appraisal, it was met by the State Malariologist, who was responsible for the team while in his state. He provided technical information and administrative services, as necessary, but he did not enter into the team's final discussion regarding the units in his state.

Each Independent Appraisal Team normally averaged inspecting one unit per day for the 2½ to 3 weeks scheduled for the field observations. The team usually stayed at a different town each evening, traveling within and between states by various modes of transportation, including airplanes, jeeps, trains, and boats. When motor vehicles were used, they and the drivers were provided by the local unit office. Each team had its own "bearer," who traveled along to prepare the meals. This was a necessity, since most of the rest houses where the teams stayed had no staff for food preparation, and there were no satisfactory restaurants in many of the stopping places. Each team also took along a clerk, who took dictation, typed reports, assembled data, prepared charts, and performed other similar services.

Upon arrival at a unit headquarters, normally the team was briefed by the Unit

Medical Officer. Then the team members reviewed the records of the program, examined maps, and asked questions in order to get a clear picture of the overall situation. The headquarters laboratory facilities were inspected, and the microscopists were interviewed. Blood slides were examined, along with the record of the results of blood slide examination. Special note was made of the epidemiological investigations of each positive case. Discussions were held with any or all of the headquarters and field staff of the unit.

After visiting the unit headquarters, whenever possible, the team made visits to the sub-units headquarters. However, the sub-unit headquarters are not considered to be as important as unit headquarters, where the major records are kept and most of the microscopic work is done. Supplies such as DDT, sprayers, and drugs may be kept at the sub-unit offices, and the team examined these when deemed necessary.

Probably the most important activity of the appraisal team was the field inspections of unit work. While each team developed its own procedures, in general, field visits were made when possible to each of the four sub-units of a unit to inspect villages and problem areas. The team chose the villages at random, and the team members selected houses within the village as they proceeded with the inspection. Frequently the team members separated and either worked as pairs or alone, in order to obtain the widest coverage possible during the limited time available. When interpretations were required, they were made by Unit Medical Officers, Assistant Unit Officers, or others on the unit staff who accompanied the team members.

It was heartening to observe the remarkable thoroughness with which the program is being executed in India and the enthusiastic reception it has received from the local inhabitants. Everywhere in India one sees evidence of the program. The initials "NMEP" undoubtedly are the most widely publicized alphabetical

designations in the country. Slogans such as "HELP US TO ERADICATE MALARIA," are found on the sides of buildings, on fences, and in other prominent locations throughout most unit areas. The team members were well impressed by the favorable comments of the local residents regarding the program. The writer, for example, in his visit to Kerala and Madras States as a member of Team III, talked to hundreds of people in scores of villages and towns. Practically everyone understood what "NMEP" is, what it is doing, and generally was much in favor of the program. They do not necessarily know the meaning of "malaria" *per se*, but they do understand that their houses have been sprayed, blood slides have been made, and drugs have been administered in order to eliminate the symptoms associated with malaria. They especially appreciate the visit of the surveillance worker who comes to each house every two weeks to inquire about the prevalence of illness. Frequently, this house visitor is the only person from the Government who has ever visited them to provide a service—and this service is given with no charge to the householder.

The only resentment toward the program noted by the writer was in areas where bedbugs had developed resistance to DDT following the residual applications to the houses, as mentioned earlier. In these areas the local inhabitants claim that the bedbugs increase much more rapidly after a house is sprayed with DDT. This could result from the destruction of certain parasites or predators of the bedbugs by the DDT, since the resistant bedbugs logically would increase more rapidly in the absence of their natural enemies. Another possible explanation is that the increase is more apparent than real. It may be that the resistant bedbugs are irritated by the DDT and are therefore driven from their hiding places, thus appearing to be more numerous.

Regardless of the explanation, the householders in these areas frequently refuse to permit the spraymen to enter their houses.

TABLE 2.—India NMEP: Recommendations of 1965 independent appraisal teams on phasing of malaria eradication units.¹

State or territory	Population ² (Millions)	Total Number Units	Recommendations for unit phasing advancements						Totals		
			Attack to consol.		Consol. to main.		Projected	Confirmed	Projected	Confirmed	
			Projected	Confirmed	Projected	Confirmed					
(States)											
Andhra Pradesh	38.20	33.50	6.00	3.93	7.79	6.79	1.00	1.50	1.00	1.00	1.50
Assam	13.46	13.25	5.43	3.05	0	0	0	0	0	0	0
Bihar	50.10	42.00	4.33	2.05	6.42	3.65	0	0	0	0	0
Gujarat	22.82	19.50	0	0	0	0	0	0	0	0	0
Jammu & Kashmir	3.70	2.00	1.50	1.50	0	0	0	0	0	0	0
Kerala	18.57	14.50	0	0	1.00	1.00	0	0	0	0	0
Madhya Pradesh	35.51	29.00	3.06	1.32	0	0	0	0	0	0	0
Madras	35.25	31.45	0	0	0	0	0	0	0	0	0
Maharashtra	43.14	33.00	5.19	4.54	9.25	9.25	0	0	0	0	0
Mysore	25.51	19.13	0.30	0.25	6.90	5.99	0	0	0	0	0
Orissa	18.97	15.00	1.32	1.32	5.20	4.49	0	0	0	0	0
Punjab	22.42	18.00	1.32	1.14	7.26	4.64	0	0	0	0	0
Rajasthan	22.23	16.67	2.10	0.98	4.25	3.15	0	0	0	0	0
Uttar Pradesh	78.75	67.00	2.79	2.13	19.75	16.00	0	0	0	0	0
West Bengal	39.57	26.00	0.16	0.16	12.37	9.05	0	0	0	0	0
(Territories)											
Andaman & Nicobar	0.06	0.25	0	0	0	0	0	0	0	0	0
Delhi	3.20	2.00	1.00	1.00	0	0	0	0	0	0	0
Himachal Pradesh	1.47	1.25	0	0	0	0	0	0	0	0	0
Manipur	0.78	2.00	2.00	1.75	0	0	0	0	0	0	0
North East Frontier Agency	..	1.50	0	0	0	0	0	0	0	0	0
Nagaland	0.37	1.00	0	0	0	0	0	0	0	0	0
Tripura	1.14	1.00	0	0	0	0	0	0	0	0	0
Coalfields	0.50	1.00	0	0	0	0	0	0	0	0	0
Laccadive, Minnicoy, Amindivi	0.02	1.00	0	0	0	0	0	0	0	0	0
Sikkim	0.15	0.50	0	0	0	0	0	0	0	0	0
Total	475.89	391.50 ³	36.50	25.12	80.19	64.01	116.69	89.13			

¹ Includes unit components (portions of several units). Each unit originally designed for approximately 1.0 million population. In February, 1965, each area included about 1.2 million persons.

² Estimates as of February 1965, based on 1961 official census, with increments.

³ Does not include 1.75 miscellaneous units.

In such a situation, health education measures are applied in an effort to impress upon the public the fact that the purpose of spraying is to eliminate malaria and not to control bedbugs. Even when the people recognize that the DDT is beneficial to them by preventing malaria, the misery caused by heavy bedbug infestations sometimes overwhelms all other considerations. When the problem is serious, Diazinon is used along with the DDT. This gives control of the resistant bedbugs, but more important, it assures entry of the spray teams and permission for them to spray.

In 1965, the 12 teams consisting of 49 team members (29 Indian officials, 10 AID, and 10 WHO) traveled perhaps 100,000 "man-miles" and visited the assigned units in 14 states and 2 territories, with an 18- to 24-day range in travel time of the teams. There were 244 "team-days" or 976 "man-days" spent by the team members in the field. The schedule was rigorous; the results were rewarding.

Upon completing the field inspection of the units, the teams returned to NMEP headquarters in Delhi to present their recommendations. A four-man review board comprised of one representative each from the Ministry of Health, the NICD, WHO, and AID, all of whom were designated as consultants⁴ to the NMEP Director, discussed with each team its findings, usually for 3 to 4 hours. The consultants then decided whether to accept, modify, or reject the recommendations pertaining to each individual unit, based upon the presentation of the team.

RESULTS OF 1965 APPRAISAL, AND PRESENT STATUS. Table 2 summarizes the results of the 1965 appraisal. The estimated population of each state and number of malaria eradication units are given for comparative purposes, along with recommendations for unit phasing advancements as made by the

1965 teams. Table 3 shows the unit phasing from the initiation of malaria control in 1953, on through the beginnings of eradication in 1958, and projected to the anticipated completion of the program in 1974. Figure 1 is a graphic presentation of the program phases—as they actually developed from 1962 to the present, and as planned through 1970.

In 1965, 36.50 units in the attack phase were recommended for transfer into the consolidation phase. After these units had been appraised by an Independent Appraisal Team and the Team recommendations had been reviewed by four consultants, 25.12 units with a total population of 30 million were recommended for the transfer (Table 2). As a result, the structures housing these 30 million people no longer need to be included in the regular spraying program.

Of the 80.19 units recommended or "projected" by the NMEP Directorate for withdrawal from the consolidation phase and passage into the maintenance phase, 64.01 units with an estimated 77 million population were confirmed as being ready for the maintenance phase.

With the acceptance of the findings and recommendations of the 1965 Appraisal Teams, the status of the program is as follows: Of the total 393.25 units in India with a population of 475 million persons at risk from malaria, only 78 units with approximately 94 million inhabitants still must remain in the attack phase (see Table 3). Many of the units that could not be advanced are in areas that border on Pakistan, China, Tibet, Nepal, and Burma, or they have some difficult problem such as geographic obstacles, poor communications, or adverse meteorological conditions that complicate control. All of these problem units, including those bordering on neighboring countries, will continue to receive special attention.

It is most gratifying to know that more than 375 million persons in India (those in the consolidation or maintenance phases) no longer require residual house spraying to protect them from this disease, which was so disabling to the people of

⁴ In 1965, the Consultants were Dr. P. R. Dutt, Assistant Director General of Health Services (Ministry of Health), Dr. S. P. Ramakrishnan (Director, NICD), Dr. G. Gramiccia (Acting Senior Malaria Advisor, WHO South East Asia Regional Office), and Donald R. Johnson (Malaria Consultant, AID).

TABLE 3.—India NMEP: Malaria eradication actual and tentative phasing schedule by unit¹ or unit components.

Fiscal year ²	Preparatory phase	Attack phase	Consolidation phase	Maintenance phase	Total
1953-54	84.00	0	0	0	84.00
1954-55	104.00	0	0	0	104.00
1955-56	133.50	0	0	0	133.50
1956-57	174.50	0	0	0	174.50
1957-58	192.00	0	0	0	192.00
1958-59	33.25	192.00	0	0	225.25
1959-60	161.00	225.25	0	0	386.25
1960-61	3.75	386.25	0	0	390.00
1961-62	0	390.00	0	0	390.00
1962-63	0	249.53	140.47	0	390.00
1963-64	1.00	161.68	228.32	0	391.00
1964-65	0.50	103.01	208.98	79.01	391.50
1965-66	2.25	77.89	170.09	143.02	393.25
1966-67	0	30.27	137.53	225.45	393.25
1967-68	0	19.55	102.25	271.45	393.25
1968-69	0	12.75	45.84	334.66	393.25
1969-70	0	4.00	28.41	360.84	393.25
1970-71	0	3.50	12.00	377.75	393.25
1971-72	0	0	3.50	389.75	393.25
1972-73	0	0	3.50	389.75	393.25
1973-74	0	0	0	393.25	393.25

¹ Each unit originally designed for approximately 1.0 million population. At present, each equals about 1.2 million. Estimates for years 1965-74 prepared by author based on discussions with NMEP Directorate and AID staff in India.

² Indian Fiscal Year begins April 1 and ends March 31.

that country for many centuries. One of the major problems confronting the program, in addition to that of continuing the spraying operations in areas where 94 million people must remain in the attack phase, is the development of adequate health facilities to assure a continued malaria-free status, which now is enjoyed by the 171 million persons in areas already in or ready for the maintenance phase of the program. The Government of India is shifting its assistance in these areas as rapidly as possible toward development of a so-called "Comprehensive Polyvalent Health Organisation." The NMEP personnel in maintenance areas are being combined with the Family Planning Organisation staff to provide a comprehensive program that will extend health services to these areas.

Family planning activities are receiving very high priority in India, second only to malaria eradication. The absence of malaria, coupled with a general improvement in health services, together with the higher

living standard brought about by improved education, agriculture, housing, communications and other developments, has resulted in a rapidly increasing population. Although it is possible through improved agricultural practices and other measures to accommodate a much larger population in India than the country now has, the Government of India feels it extremely important that the size of families be limited and is making remarkable progress in this direction.

Insofar as the staff of the new health organization is concerned, NMEP personnel can be readily trained to provide other health services in addition to malaria. For example, laboratory technicians already skilled in the use of microscopes easily can learn to identify intestinal parasites, and a variety of other organisms, with a minimum of additional training. A medical malariologist can, of course, assume much broader responsibilities in the field of public health, usually with no additional training required. This staff

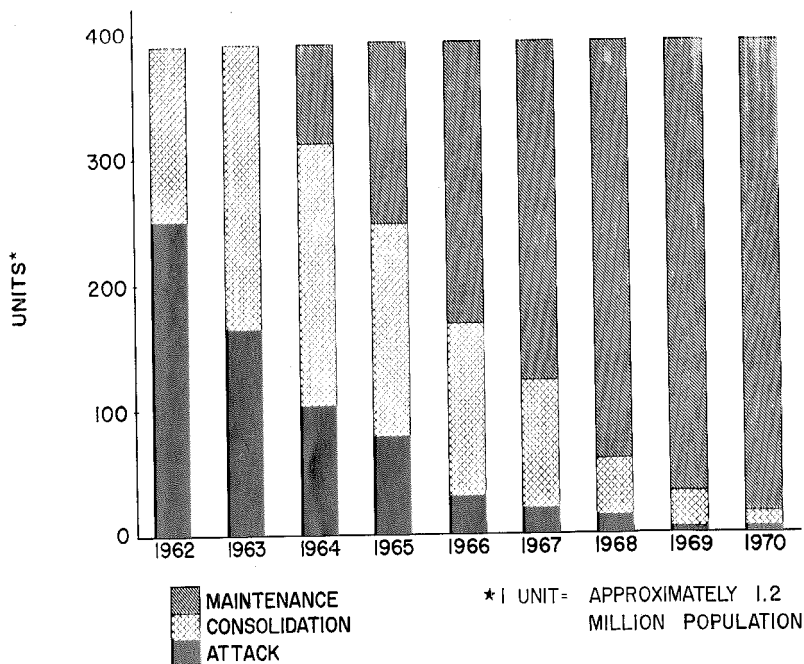


FIG. 1.—India National Malaria Eradication Program status and future phasing (tentative—as of February 1965).

will, as a part of the expanded program, help to prevent reintroduction of malaria into these areas.

India already has made magnificent gains in its remarkable fight against malaria. A well-disciplined organization utilizing modern public administration methods was built up within the governmental framework and functioned effectively to accomplish a job within a short period of time. With continued national support and international cooperation, the people of India will, in the foreseeable future, be entirely freed of this heavy burden.

The malaria eradication campaign, however, is doing more than eliminating this one disease. It has shown the Government and the people, through a good vector-control program coupled with progressive medical and public health practices, that something *can* be done about improving the health and general well-being of the

entire population. In this way, the foundation has been laid for an expanded program of permanent health services that rapidly will become a positive influence on all facets of life in modern India. Through this campaign, India is proving that an up-to-date health program is a basic requirement for progress in all fields of national development. This by-product of malaria eradication may become even more important than the total elimination of the disease itself. The future appears to be most encouraging and health workers everywhere wish India well in its dramatic endeavors.

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COMPARATIVE OBSERVATIONS ON WINTER SURVIVAL AND HATCHING OF *Aedes vexans* EGGS IN TWO LOCALITIES—FLORENCE, ALABAMA, AND ST. PAUL, MINNESOTA

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INTRODUCTION

To workers concerned with the control of floodwater mosquitoes, particularly *Aedes vexans* (Meigen), the importance of knowing more about the dormancy mechanism in the egg stage is obvious. The literature is especially scant and often conflicting on the winter survival and dormancy of the eggs. The situation is complicated by the fact that various workers have noted apparent differences in the winter behavior of *vexans* eggs from place to place, and questions frequently arise

regarding the existence of a "diapause" in the species.

Recent independent investigations by Tennessee Valley Authority biologists and by entomologists from the Metropolitan Mosquito Control District (Minnesota) led to discussions which indicated a different winter behavior pattern of *vexans* eggs in the two localities. Eggs constituting the Minnesota winter population showed a dormancy beginning in late summer or early fall, highly indicative of diapause. By contrast, eggs from Alabama populations had been observed to hatch at any time when properly flooded during the winter months.

Discussions arising from these independent observations led to a preliminary cooperative experiment during the winter of 1963-1964 in which soil samples were removed from *vexans* habitats concur-

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