Chapter VII

STRATEGIC EXPANSION OF DDT SPRAYING

The primary objective of the four-year malaria control program was to bring the disease under control and to reduce the incidence of malaria to a point where it would no longer constitute a public health and a socio-economic problem. It was originally planned that DDT spraying operations be conducted extensively in the nalarious areas for three years on an island-wide scale following a pilot project. The DDT spraying would then be suplanted by surveillance activities integrated into the general health services to control or eventually eradicate the disease.

The results of the pilot project indicated that *An. minimus*, the principal vector, was very sensitive to DDT and that it practically disappeared from sprayed houses and other structures. Malaria transmission seemed to be completely interrupted, as evidenced by the absence of new infection in the monthly infant surveys. Both spleen and parasite rates fell rapidly after the spraying. The cost per capita for an annual application of the insecticide was NT$2.35 (or US$0.23), of which 63.54% was the cost of DDT, 20.81% labor, and 15.65% other expenses.

The program was very much welcomed and supported by the people and, in fact, the costs of labor were borne by the local township governments. Furthermore, the field operations were effectively carried out by the local health personnel once they had received training by TAMRI. The communities were evry appreciative of the program and were willing to collaborate. With all experience gained from the pilot project, it appeared evident that malaria eradication in Taiwan was an attainable goal which should be pursued with intensified efforts while favorable conditions existed. The original strategy to control malaria, to be followed by long-term surveillance to eliminate the remaining sources of infection, was seriously re-evaluated.

While the 1954 spraying program was still in progress, the original strategy was modified to extend the island-wide spraying coverage for two more years--1956 and 1957 (Fig. 41). The 1956 spraying coverage would include the entire island, except the centers of large cities where there was no danger of malaria transmission. Also excluded were the Penghu Islands and Lutao Island, which were non-malariaous. In 1957 the area to be sprayed would be reduced to the original hyperendemic areas and the aboriginal areas. A proposal was made in January 1955 to the Foreign Operation Administration (FOA/USA) and CUSA for continuation of

financial assistance to purchase DDT and spraying equipment. The proposal received favorable consideration by both agencies, and the needed funds were assured. Thus, during 1953 - 1957 inclusive, the originally hyperendemic area received DDT spraying for five consecutive years, the aboriginal and mesoendemic areas for three years, and the hypoendemic or non-malarious coastal plains for only one year (Maps 6 and 7).

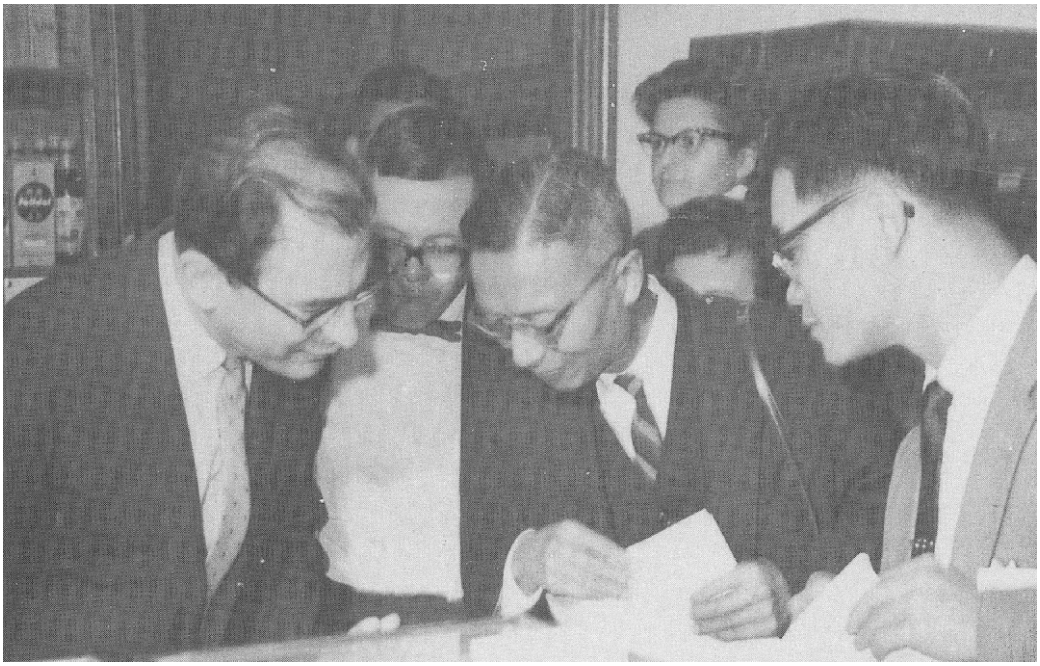
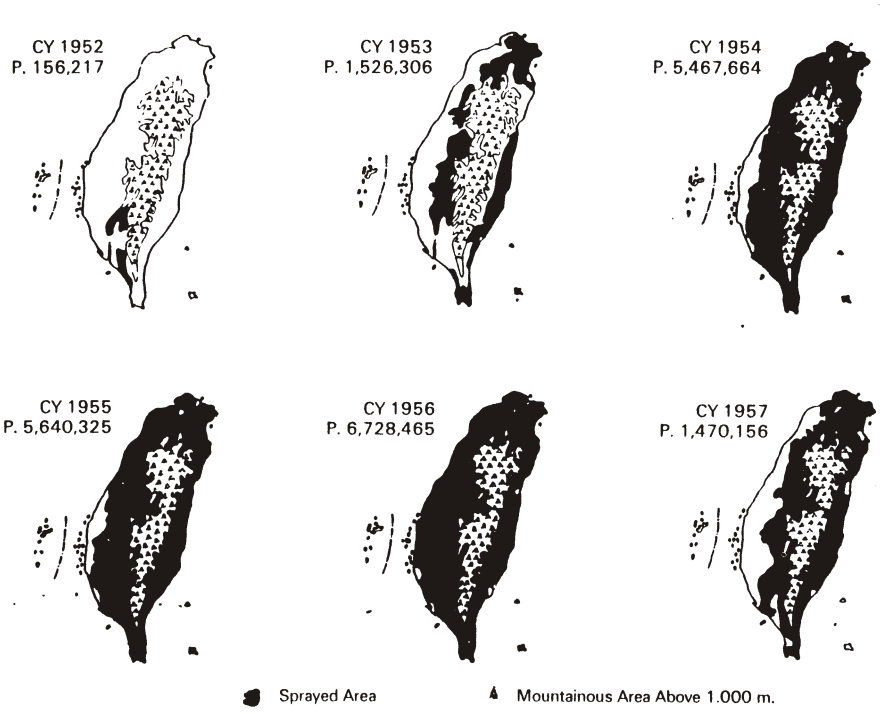


Fig. 41: Dr. Shih Chu Hsu (center), Chief, Rural Health Division, JCRR, reviewing six-year malaria eradication program

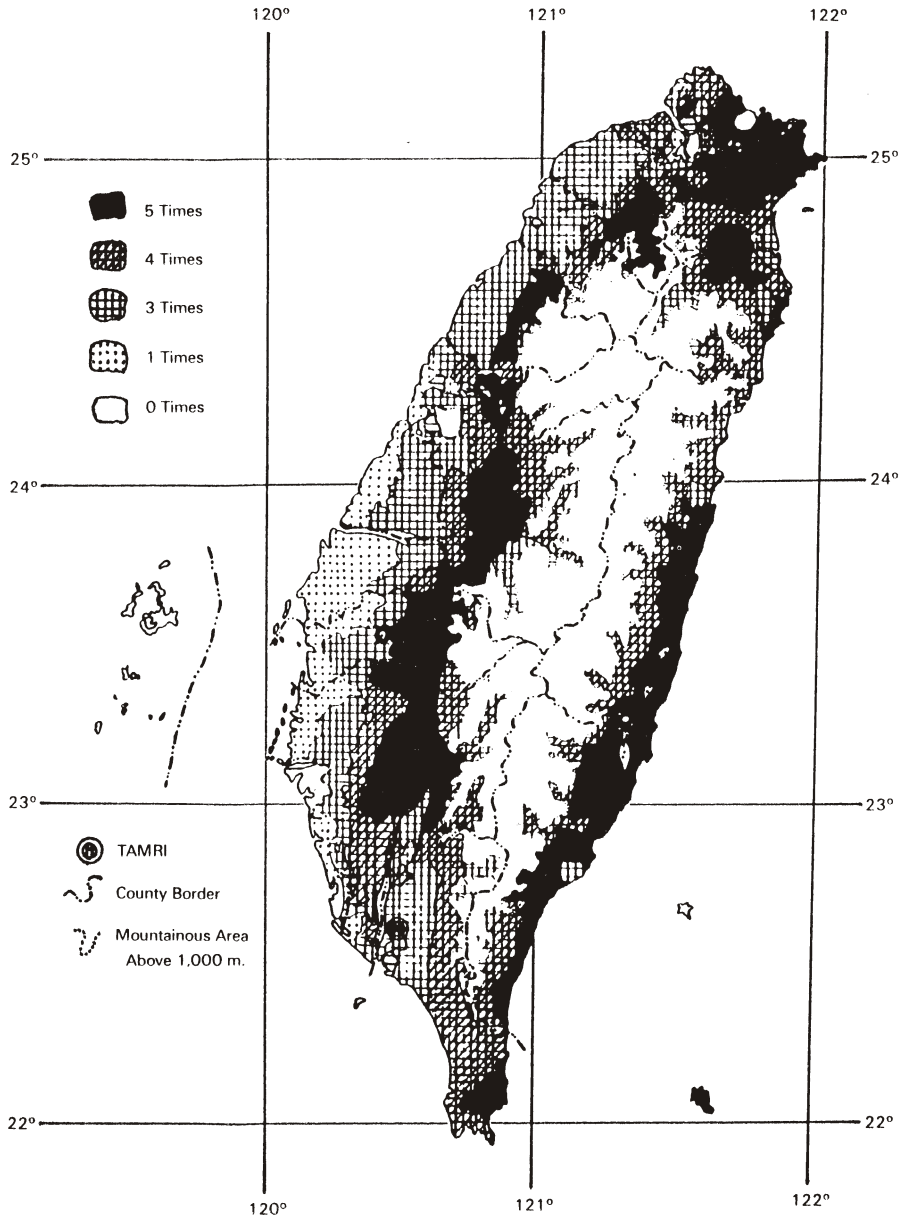
Map 6

Six-Year Malaria Eradication Project,
DDT Spraying Coverage in Taiwan, 1952 - 1957



Map 7

Frequency of Spraying Operations, 1953 - 1957



ANNUAL PLAN OF ACTION

Based on an operational area defined for a given year, a detailed plan of field action was worked out. This annual plan of action would then appear in the *Taiwan Provincial Gazette* as the official directive from the provincial government to the local governments. As an example, the *Taiwan Provincial Gazette* of November 5, 1953 announced the 1954 spraying program as follows (translated literally from Chinese):

* The government of the Republic of China, WHO and US aid organizations are undertaking island-wide malaria control operations in Taiwan. The program will enter its third year in 1954 and will include the malarious areas which are listed below with the population of each township involved;

* DDT and sprayers are provided by the foreign aid organizations. TAMRI shall provide subsistence and lodging for the trainees and defray the transportation cost of DDT and sprayers from the manufacturers to county health centers;

* Townships shall provide a fund of NT$ 1.00 per capita (based on the population to be protected by spraying) for local operational expenses other than those mentioned above. Such funds shall be included in the annual health budget of the respective health stations.

Cost of operation in the aboriginal townships may be provided, upon request, by the provincial government;

* Township shall provide personnel required by the program, the number of which is listed herewith. Supervisors and foremen shall be selected among the employees of the respective townships (preferably from the health station and the township office) and shall work full-time for the period of spraying operation - about 60 working days. Their per diem shall not be less than NT$10.00 per person per day;

* County, municipality and special district health centers, in addition to their normal health budget, shall provide NTS10.00 per

1,000 population for DDT spraying publicity campaign and NT$50.00 per 1,000 population for supervisory activities;

* Operational procedures, timetables, training schedules and other technical and administrative arrangements shall be notified by TAMRI separately; and

* The appended list shows the estimated population for and the number of foremen, spraymen and helpers required by the spraying program in the respective townships. (Note: the township with three or more foremen shall provide one extra person to be in charge of the program. He shall be called the township supervisor. The township with one or two foremen shall assign one of them to be the head foremen.)

The Taiwan Provincial Gazette of June 4, 1955 directed that the township malaria budget be allocated as follows: 76% for wages of the temporary spraymen and the subsidies and travel expenses of the foremen; 7% to cover travel expenses required by foremen for attending regional training courses and the expenses in carrying out local training courses for spraymen and helpers; 3% for costs of transporting DDT and sprayers from the county health center to the township health station; 12% for miscellaneous expenditures e.g., publicity campaign, purchase of accessory equipment and repair kits, and special cash awards for outstanding workers; and 2% as a reserve to spray newly-constructed houses missed during the regular spraying schedule. Release of any reserve funds requires approval by the respective county health officer.

TRAINING OF SPRAYING PERSONNEL

There were two major groups of personnel engaged in the island-wide spraying operations -- one, the full-time, specialized group at TAMRI, and the other, the health workers at county health centers and township health stations who worked for the malaria program only during the spraying period (about two months).

The TAMRI group, namely the engineering section of TAMRI, consisted of a medical officer, two engineers, 16 field supervisors, two mechanics, one draftsman, one clerk and four drivers. They were the only full-time spraying personnel

throughout the entire DDT spraying period - 1952 through 1957. Their field experience was gained before 1952 when TAMRT was undertaking experimental

Fig. 42: Personnel of the engineering section

the selection of foremen. However, some townships were allowed to hire temporary workers as foremen when they were unable to fill the positions with existing staff members. As might be anticipated, the temporary foremen were generally not as enthusiastic and responsible as the permanent employees. Among all the foremen engaged in the spraying operations, health personnel represented 55% in 1953, 29% in 1954, 24% in 1955 and 22% in 1956.

As soon as the spraying season was over, the permanent employees selected as township supervisors and foremen returned to their former jobs. The great majority of them returned to work in the same or similar capacity for the malaria program in subsequent years. While working for the malaria program, they were paid per diem from the township malaria funds. The educational background of the township supervisors and foremen was of considerable interest: 17% primary school, 42% junior high school, 31% senior high school, and 7% college or public health course graduates.

Spraymen and helpers were wage-earners on a temporary basis. Their recruitment was made chiefly by the township supervisors and foremen. Priority was given to young men 20-30 years of age. Sometimes a physical examination and/or written examination was given to the candidates. They were discharged at the end of the two-month spraying season. Many of the temporary workers returned year after year for re-employment. The turnover was about 40%.

Regional Training of Township Supervisors and Foremen

From 1953 to 1955, training was arranged on a regional basis - central, northern, eastern and southern Taiwan. At the beginning of each year or at the end of the previous year, a single special training class was held at TAMRI for 28-35 county supervisors, the key personnel for the respective county spraying programs. These county supervisors later assisted in regional training courses for township supervisors and foremen. Usually one class was held in each region for township supervisors, followed by one or two classes for foremen held at the same site, using the same facilities. The number of trainees, both township supervisors and foremen, averaged 100 per class, ranging from 50 to 150.

Regional training courses were usually conducted locally, within the respective region, utilizing schools or assembly halls as class rooms. Furniture, teaching material, equipment and supplies needed for classrooms were procured or borrowed locally insofar as possible. Only the critical items which could not be obtained locally were brought to the class by TAMRI personnel. Such items were

well packed into 2½ ton pickup trucks which moved from one region to the next very much like a traveling circus. Among the items carried by the TAMRI's mobile training team were dozens of 3-meter bamboo poles and cloth sheets (2.3 m long x 4.35 m wide = 10 m^2) for use in practicing spraying techniques. A piece of 10 m^2 cloth, fully stretched between two bamboo poles set up in the schoolyard, was used to provide the flat surface for two squads, one practicing on one side of the cloth screen and the other on the opposite side, if necessary. Bamboo screens were also used if available. Spraymen were first trained to spray a 2.3 m vertical swath in exactly five seconds, while keeping the spray-fan at right angles to the direction of motion, and the lance tip at 45.7 cm (18 inches) from the surface being sprayed. They were next trained to consistently spray 20 m^2 (12 successive vertical swaths) in one minute, using the same technique. Even a large class of 150 trainees was able to practice spraying techniques with 10 cloth screens set up on a schoolyard, under close -- literally close -- supervision. Such a scene was very spectacular, attracting local officials and other spectators (Figs. 44, 45 and 46).

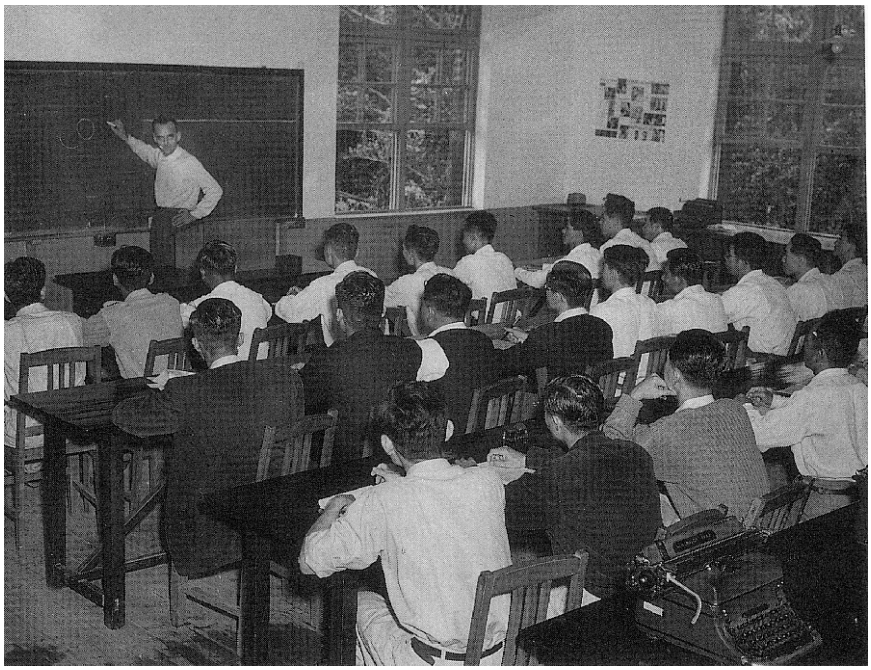


Fig. 43: Special training class held at TAMRI for county supervisors, 1953

Local Training of Spraymen and Helpers

As soon as the regional training was over, the township supervisors and foremen returned to their respective townships and in turn trained their spraymen and helpers locally. Training the spraymen and helpers together created a ready pool of spraymen when any of the latter left (which was not unusual) during the operations. The county supervisors and their TAMRI counterparts visited the township classes to supervise or supplement the training activities. Since spraymen and helpers were officially on payroll from the start of their training, field spraying operations began immediately after completion of their training courses.

In every region, it usually tool a month to complete the training of personnel at various levels. During this period, every township supervisor went through three different types of training -- first as a trainee, second as an instructor assistant, and third as an instructor. A foreman went through two courses -- one as a trainee and the other as an instructor assistant. The training process was repeated every year, even though the majority of the county and township supervisors and foremen were re-selected to assume the responsibility of spraying operation in subsequent years. Because field operations were decentralized in Taiwan, local government employees were assigned to the spraying program for a period of only three months a year - one month for training and two months for spraying. This meant that for the other nine

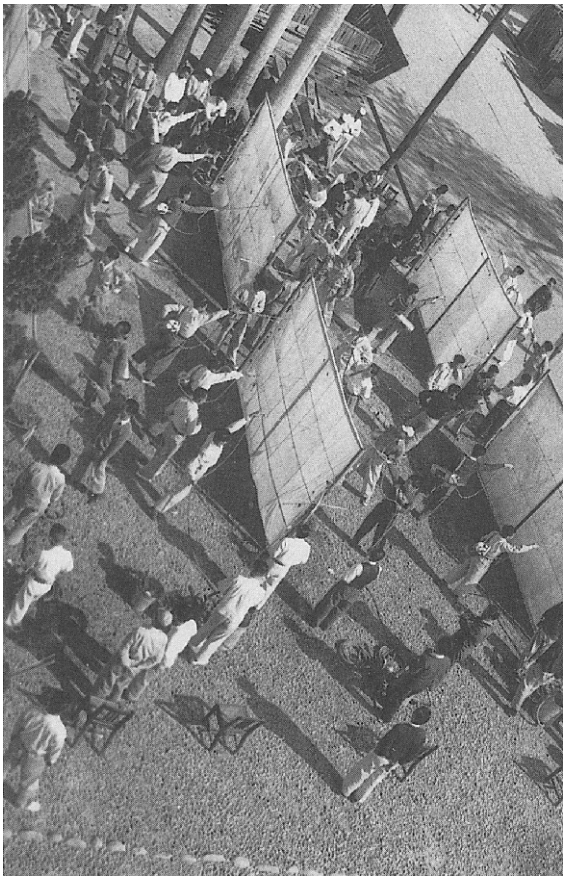


Fig. 44:

Using cloth screens to
Practice spraying technique

Fig. 45: Using bamboo screens to practice spraying technique

Fig. 46: Practicing spraying technique

months of the year, the employees were not involved in spraying and would therefore need at least a refresher course to update their knowledge and spraying technique when they returned to the task the following year. Furthermore, there were always newcomers joining the program every year, who would require a full training course. For these reasons, it was considered essential to repeat the whole process of the training program every year just before the start of the spraying operations.

In 1953 and 1954, classroom instructions were given by TAMRI and WHO

personnel, with county supervisor serving as assistants in field practice. In 1955 the county supervisors participated in classroom lectures and conducted field practice with little assistance from TAMRI personnel. In 1956 the training procedures were further decentralized. Training was shifted from a regional to a county basis. Each county arranged its own classes for township supervisors and foremen. Lectures and field practice were conducted almost exclusively by county supervisors, with TAMRI personnel serving as advisers.

Trainees, regardless of level, were organized into squads, each consisting of seven members as if they were to engage in actual spraying operations. Among the seven members, one was assigned as the squad leader and the others as spraymen and helpers. They rotated their assignments during the training period, so that every member had the opportunity to work as a helper, as a sprayman, and as the squad leader. Despite the large size of classes, the necessary instructions were given efficiently in a short period of one week. Table 27 sums up the training courses for spraying personnel during the period 1952 - 1957.

Table 27

Summary of Training Courses, 1952 - 1957

Description	1952	1953	1954	1955	1956	1957
Number of regional training sites	1	4	6	5	17	18
Number of regional courses	1	6	11	12	25	18
Number of trainees (all categories)	140	1,284	6,306	6,578	7,795	1,972
- county supervisors	----	29	28	35	35	28
- township supervisors	----	----	159	189	214	40
- foremen	28	271	881	908	1,078	272
- spraymen	112	984	5,238	5,446	6,468	1,632

Usually on the fifth day of the spraymen's training course, the township mayor would invite council members, village chiefs, heads of local government agencies, policemen, newsmen, and other influential people of the community to come and observe the spraying practice and to solicit their collaboration in implementing the malaria program (Fig. 47).

Fig. 47: Mayor of Chishan explaining DDT spraying to policemen

Curricula of Training Courses

Although the curricula for courses of different levels were not identical, the basic organization of the classes, the training procedures and the emphasis on good spraying were the same. There was considerable overlap in the curricula for the township supervisors and foremen. This repetition was considered of positive educational value. In fact, important instructions were repeated almost every day in every class; for instance, a simple sentence, "Do not forget to spray the underside of beds," was repeated almost every day by all the instructors.

Fig. 48:

"Do not forget to spray
the underside of beds."

Fig. 49: The difficult job of spraying
the underside of platforms

The house-spraying itself required very little technical knowledge as far as workers were concerned. The curricula thus emphasized spraying techniques in great detail, while entomologic and malariologic presentations were brief. Generally speaking, the training courses emphasized physical drilling and field practice with minimum presentation of theory in lectures and discussions. However, from 1955 forward, more advanced training material was included in the supervisors' course to meet the progressive stage of the survillance program. Table 28 shows the allocation of hours by subject matter for various types of training courses in 1955.

Table 28

Curricula of Training Courses in 1955

Subject	County* Supervisors	Township Supervisors	Foremen	Spraymen
Administrative and general discussion	6	6	6	6
Parasitology	8	3	2	0
Entomology, lecture and field	14	3	3	0
Spraying equipment, lecture and field	10	6	3	6
Field spraying technique	10	14	18	32
Recording and reporting	6	3	5	1
Supervisory technique and evaluation	16	7	6	0
Total (hours)	70	42	43	45

* Special course held at TAMRI.

To facilitate training and also to provide a source of reference, two practical instruction manuals were prepared by the engineering section of TAMRI (see Chapter VI).

It may be of interest to mention that at the regional training course for northern Taiwan in 1958, almost equal numbers of trainees indicated their preference for instruction in Taiwanese and in Hakka, while some chose Mandarin and a minority from aboriginal townships elected Japanese. This apparently reflected the social and cultural transition of the post-war period.

FIELD OPERATIONS

Timing of Spraying

Based on the picture of malaria transmission from pre-spraying studies, the island was divided into four operational regions for DDT spraying (Table 29).

Table 29
Regional Timing for Spraying

Region of Taiwan	County or Municipality Included	Start	Completion
Central	Taichung county, Taichung municipality, Nantou county, Changhua county, Yunlin county, Chiai county	February or March	April or May
Northern	Taipei county, Taipei municipality, Keelung municipality, Taoyuan county, Yangmingshan Special District, Shinchu county, Miaoli county	April or May	June or July
Eastern	Ilan county, Hualien county, Taitung county	June or July	August or September
Southern	Tainan county, Tainan municipality, Kaohsiung county, Kaohsiung municipality, Pingtung county	August or September	October or November

DDT spraying operations in a region usually began one month after the commencement of the regional training. While the township supervisors and foremen were still in training, DDT and spraying equipment were delivered to the townships in the region through respective county health centers, and operational funds were made available by the township mayors. With these funds, accessory equipment was purchased or repaired before the start of the spraymen's training. During the foremen's training course, village-by-village spraying schedules for each township were prepared by the respective township supervisors and foremen, assisted by the county supervisor and his TAMRI counterpart. Flexibility was

provided in the schedule to permit certain inevitable delays due to transportation, bad weather and other unpredictable complications.

Spraying Technique and Sequence

Basically, the techniques used in spraying operations and the sequential steps involved followed those set in 1952 in the Chishan pilot project (see Chapter VI). Figs. 50 through 55 illustrate some of the aspects in house spraying conducted in villages.

Fig. 50: Preparing a house for spraying

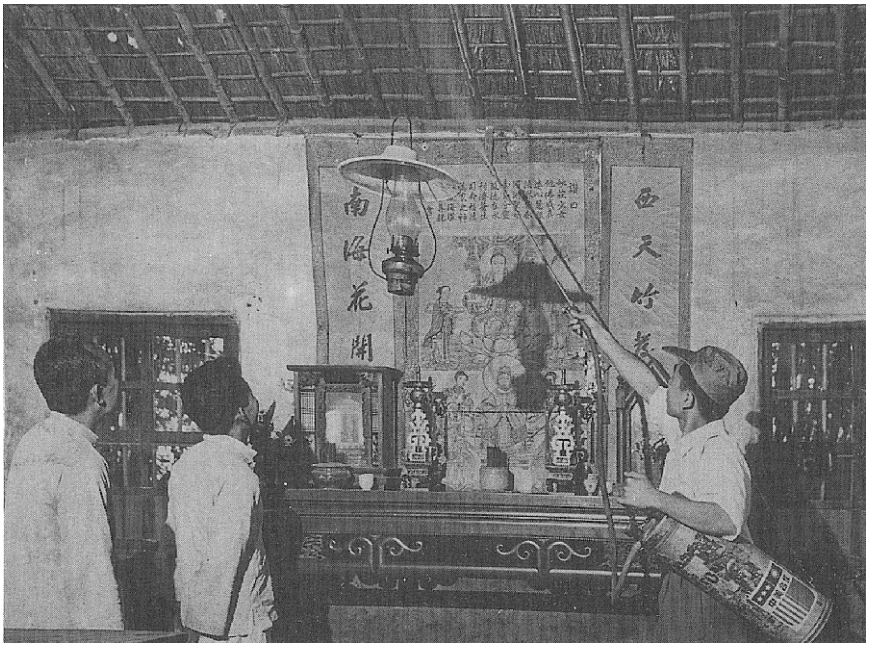


Fig. 51: Ceiling of a house being sprayed
Source: JCRR

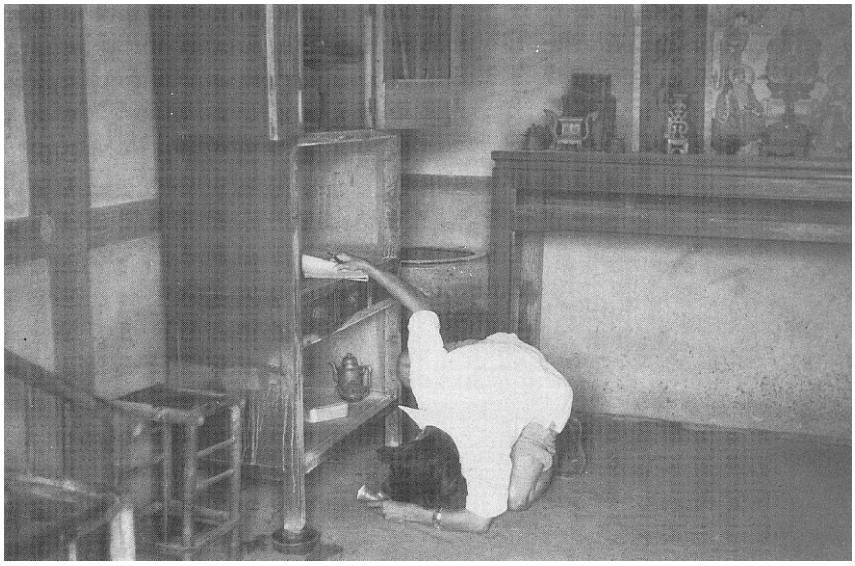


Fig. 52: Foreman inspecting DDT deposits

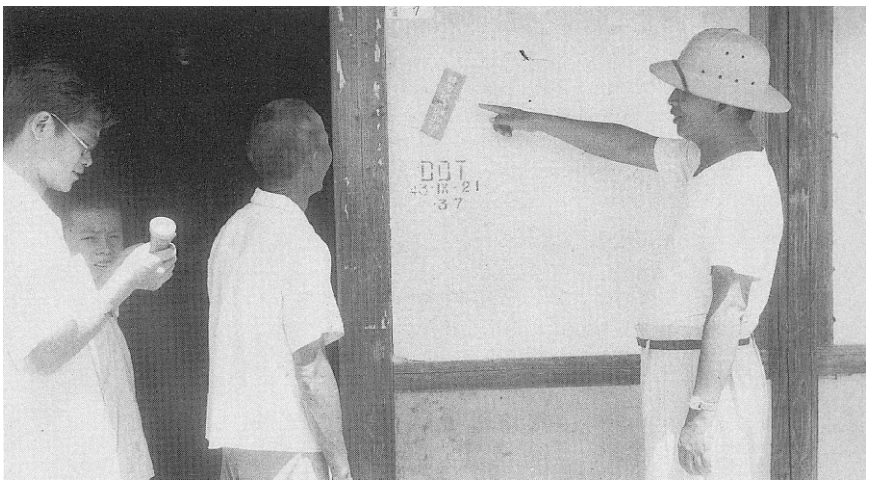


Fig. 53: Warning strip on doorway reminding residents:
"Do not wipe off DDT deposits."

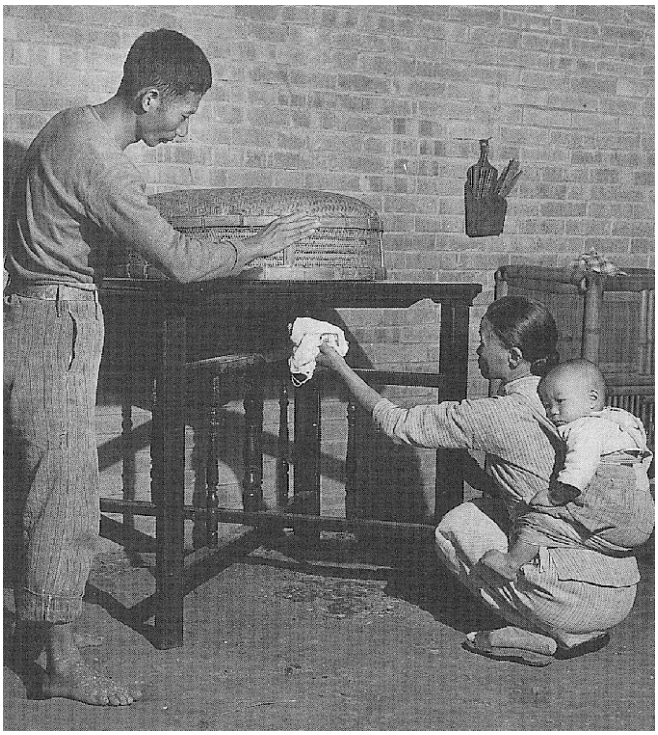


Fig. 54:

"Do not wipe off
DDT deposits."

Source: JCRR

Fig. 55:

Warning strip on the doorway of a house sprayed with DDT, bearing the messages:

Center column: "Do not wipe off DDT deposit".

Right column: "Spraying once a year is effective to avoid malaria infection for one year".

Left column: "Controlling malaria with DDT is for you, for me, and for everybody".

Lower portion: Inspection certificate showing "Date" sprayed and the responsible spraying squad.

Equipment, Supplies and Transport

The success of a nation-wide DDT spraying program as operated in Taiwan depended largely on good administrative support. The program required not only a sound organization with competent staff, but also an efficient administration to provide timely allocation of supplies, equipment and adequate – albeit limited -- operational funds.

Throughout the operations, 75% DDT water-dispersible powder (wdp) was used, with the exception of about 5,670 kg of 50% wdp used in 1952 in the demonstration area. Initially all DDT was imported from the United States through ICA. However, from 1953 the local DDT plant, Taiwan Agricultural Chemical Works (Fig. 56), began to manufacture DDT. Each lot of DDT was tested by the Dalare Associates, USA, to ensure conformity with WHO specifications. The plant supplied one third of the required insecticide in 1953, one half in 1954, four fifth in 1955, and all of the requirement in 1956 and thereafter.

Fig. 56: Taiwan Agricultural Chemical Works
(DDT plant in Kaohsiung city)

A variety of sprayers was used in the project, especially in the beginning, such as Hudson-710MS, 735MS, Climax Junior, X-pert type compression sprayers; Smith's, E.C. Brown's, and Tacheng's hand compression sprayers (local). Also in use were multi-outlet pumps manufactured by a Japanese firm and a local model of the same type of pumps by Tacheng Iron Works (Figs. 57 and 58). Originally, the sprayers were all imported, but agonizing delays in procurement and shipment frequently threatened to cause interruption of field operations. For this reason, local manufacturers were encouraged to produce samples for testing by the engineering section in accordance with the FOA specifications. As a result, the Tacheng Iron Works in Taipei succeeded in producing both hand compression sprayers and multi-outlet pumps in 1954.

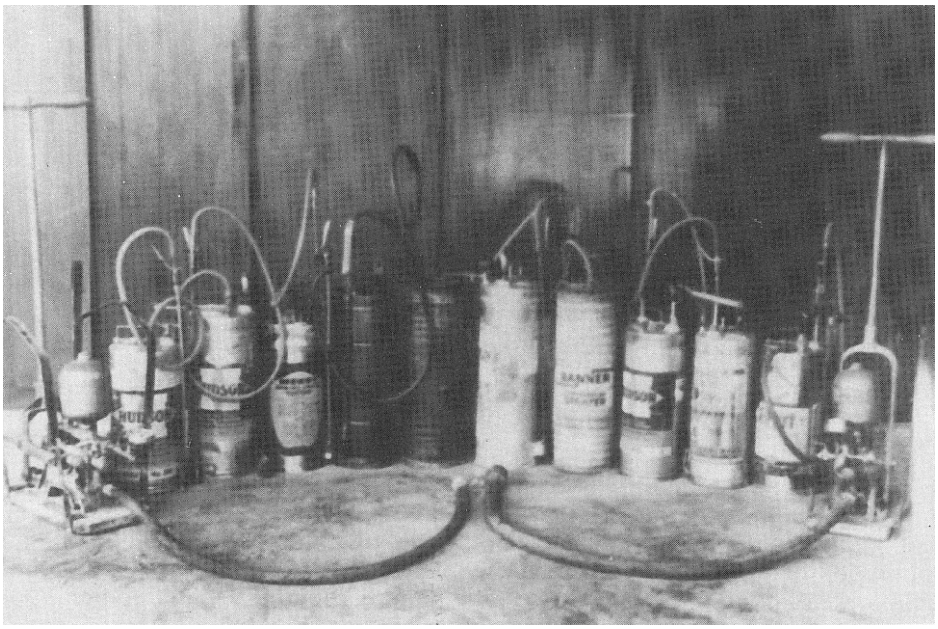


Fig. 57: Variety of hand compression sprayers

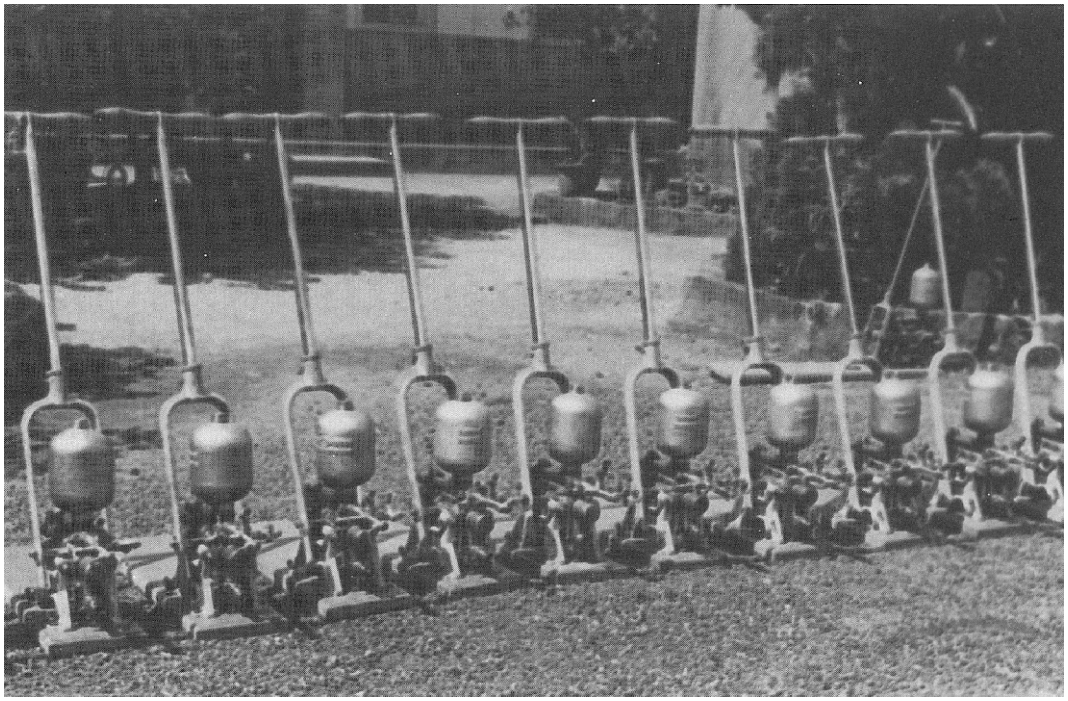


Fig. 58: Multi-outlet pumps

In addition to DDT and sprayers, every squad carried a set of standard accessories and tools for field operations. These items were procured locally before the spraying season, using the township malaria funds. A list of the required items and specifications was published in the operational manual (Fig. 59).

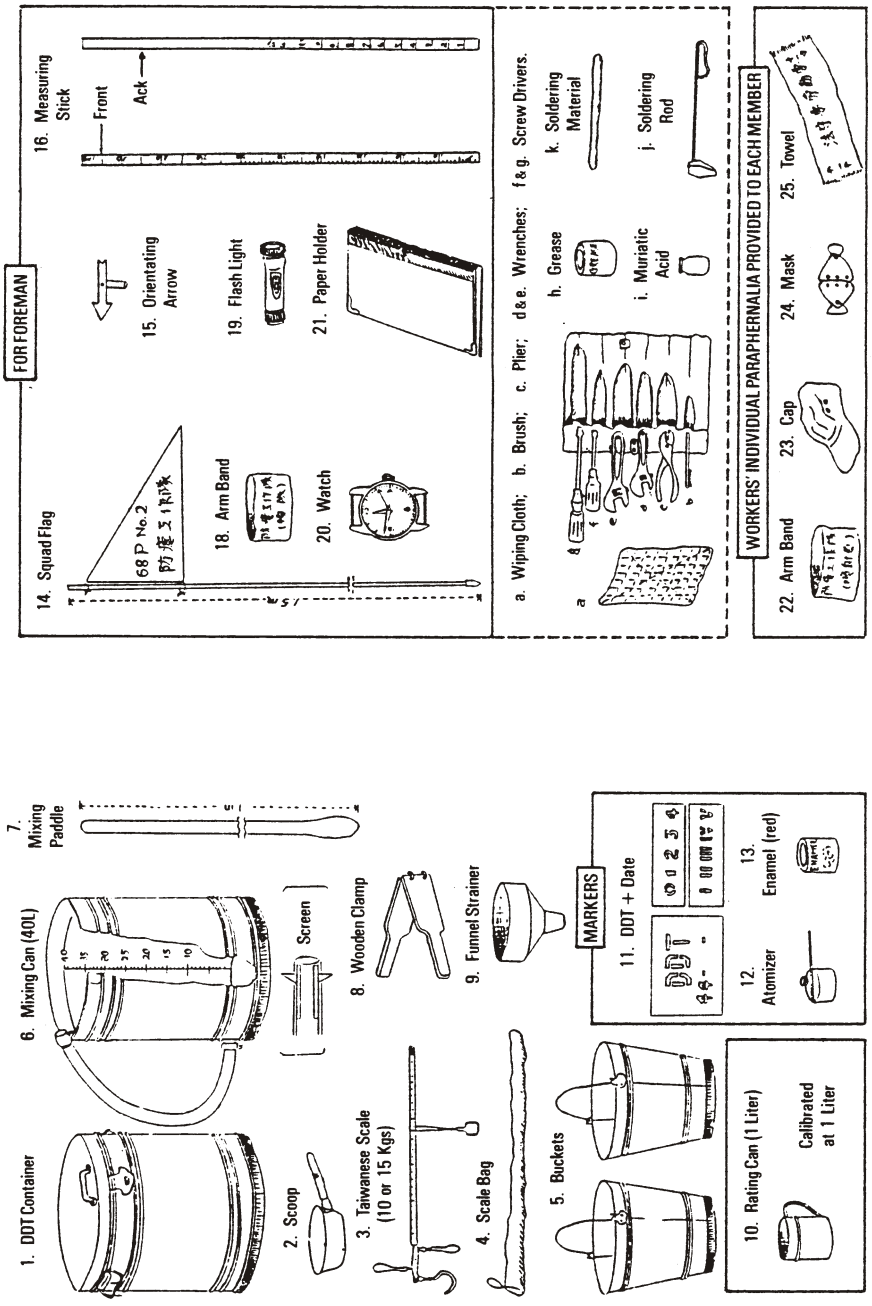


Fig. 59: Accessories and tools

Allocation of sprayers and DDT was made to each region while training courses were being conducted. Both sprayers and DDT were transported directly from customs warehouses or local manufacturers (Fig. 56) to each county health center, from which they were distributed to various townships (Figs. 60 and 61).

Fig. 60: Transportation of DDT

(DDT was usually transported from the DDT plant to counties by cargo-train; from counties to townships by any available means of transportation.)

Fig. 61: Spraying squad transporting its own DDT and equipment in remote mountainous areas

Source:JCRR

In addition to sprayers and DDT, each squad had a set of standard accessory equipment (purchased locally with township funds) following the specifications set by TAMRI. Upon completion of spraying, all sprayers and any balance of DDT were shipped to TAMRI through county health centers, but the accessories remained with the health stations for re-use in the following years' operations. All sprayers were checked and reconditioned by TAMRI (often cannibalized) at the end of the year for re-use in the following season.

Numerous difficulties occurred initially when operations depended on importation of insecticides and sprayers. In the first place, the date of arrival was uncertain in most cases. On one occasion, the whole operation in a region was delayed because of the late arrival of 100 metric tons of DDT. On another occasion, the delay of over one year of 825 sprayers forced TAMRI to undertake emergency

transfer of sprayers directly from central and northern Taiwan to fill the requirements of the spraying crews in southern Taiwan. As spraying operations were scheduled to be completed before the expected peaks of anopheline prevalence, any delay in work could result in unfavorable epidemiological consequences.

Secondly, in the case of sprayers, the procurement agencies abroad did not always send the kinds of sprayers specified by TAMRI. This accounted for the use of many different kinds of sprayers (Fig. 57), some of which had interchangeable spare parts, some of which did not. Major problems resulted from inflexibility on the part of procurement offices of well-intentioned donors. Despite reminders by TAMRI and WHO specialists that changes in brands and models of sprayers could cause innumerable problems in training spraymen, incompatibility of spare parts, and eventual cannibalization of older units, slightly lower bids were often accepted without consulting the users. The TAMRI records showed that on several occasions the cheapest equipment was often the most expensive in terms of operational schedules, labor losses, reduced efficiency and higher maintenance costs. In the worst instance, in 1953, the almost simultaneous collapse by implosion of more than 75 pump cylinders in various parts of the island seriously affected spraying operations (Fig. 62). Fortunately TAMRI's replacement, using local material at almost prohibitive cost, permitted resumption of operation well before the arrival of the manufacturer's air-shipment of replacement parts.

Problems such as these, which caused nightmares in many cases, were solved only by the local production of acceptable DDT and sprayers. The unit price of local products was slightly higher, but the gratifying sense of self-sufficiency represented a great gain in many respects.

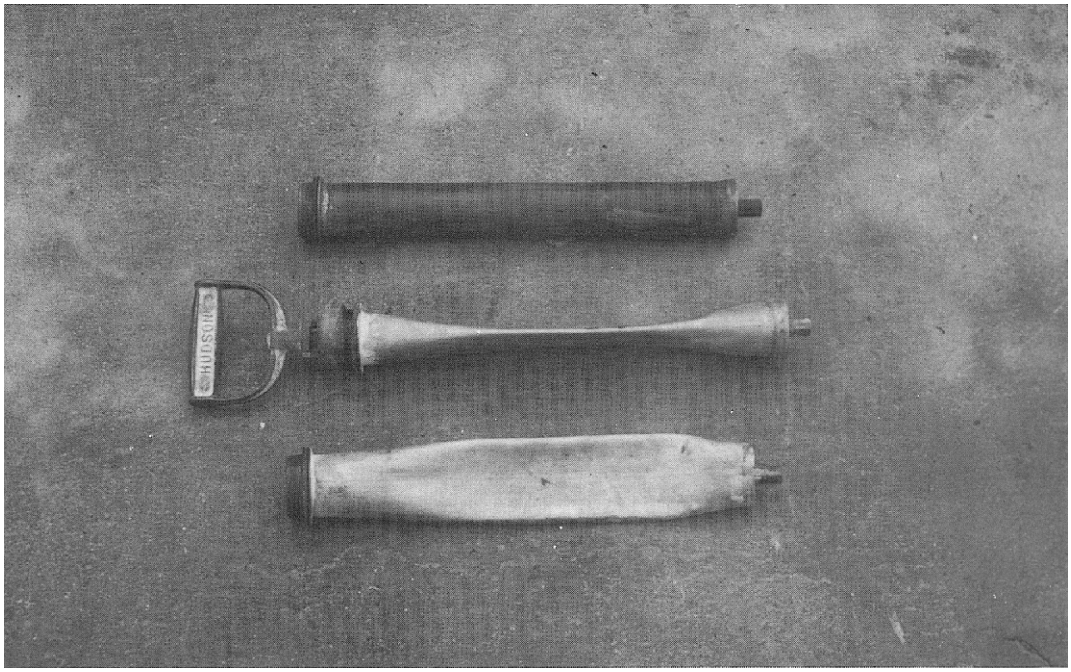


Fig. 62: Collapsed pump cylinders

Reporting and Supervision

A good reporting system is essential to ensure timely assessment of the progress of work. In order to assess the progress of work, it was necessary for TAMRI headquarters to maintain close contact with field supervisors at all levels. This was particularly critical in Taiwan where field operations were run by local health personnel under an extremely decentralized system. Each foreman submitted a report to his township supervisor at the end of each day. The township supervisor, having collected all the daily reports from the foremen, checked them carefully with each foreman. At the end of the week, each township supervisor in turn prepared a weekly summary, which was submitted in triplicate to the county supervisor for his review and comment. After his review, the county supervisor sent one copy back to the township with his comments, kept one copy in his file and passed one copy to TAMRI headquarters through his TAMRI counterpart. At the completion of the operation, the county supervisor and his TAMRI counterpart produced a summary of the spraying operations and submitted it in duplicate to the county health officer - - one for his file and the other for TAMRI.

As mentioned under Chapter VI (Pilot Project in Chishan District), the progress of work was posted at each health station on a bulletin board, showing the coverage of population, the number of houses, the consumption of DDT, the exact location of each squad, etc. Each squad carried a flag which was placed at the nearest road or trail with the arrow pointing in the direction in which the squad was working (Fig. 32 in Chapter VI). Health officers and field supervisors at all levels were constantly visiting spraying squads during the period of spraying operations (Fig. 63).

In summary, by means of daily reports submitted by squad foremen and weekly reports from townships supervisors, each county health officer, through his designated malaria supervisor, was well informed of field activities, including problems requiring his attention and support. Similarly, TAMRI headquarters, through its posted counterpart of the county supervisor, received the same information which would permit analyses of field operations, evaluation of work progress, identification of operational and administrative problems, and actions by TAMRI to support local health officers, as necessary.

Fig. 63: Review of spraying record by
Dr. W. Ross Cameron, MSA Health Officer

Analyses of Spraying Operations, July 1952-October 1957

The geographical area covered in 1952 (Pilot Project) was rather extensive, but the houses were few and small, usually scattered along foothills or in valleys. Typical of the houses in the rural areas, the average number of rooms, surface area, and number of inhabitants per house were small. Furniture in these rural houses was sparse and usually of simple design. Accordingly, the consumption of DDT per structure or per capita was relatively small. The time required to spray a house was less, but the time spent for travel between houses and villages was greater in 1952 than in other years.

As the program expanded its coverage year after year from 1953 to 1956, more and more urban areas were included. The houses in these areas were more complex than those in the rural areas, with more rooms and furniture per structure. The average surface area per structure was larger, and naturally more DDT was consumed in comparison with that used in 1952. The time required to spray a house was greater, but the time spent for travel was less in the urban area than in the rural community. Table 30 shows the differences in value, through the analyses of the results of spraying operations, from year to year between 1952 - 1957. In the interpretation of the 1957 figures, it must be taken into account that the geographical area covered in that year was similar to that covered in 1953, plus all "mountain townships" where houses were small and scattered along valleys.

Table 30

Analyses of Spraying Operations, 1952 - 1957

Description	1952	1953	1954	1955	1956	1957
Per structure analyses:						
- man-hour labor spent by spraymen	1.10	1.57	1.43	1.50	1.47	1.16
- number of rooms	6.83	7.92	7.97	8.86	8.83	8.39
- number of inhabitants	7.20	8.27	8.29	8.94	9.21	8.48
- surface area sprayed (m^2)	305	337	365	402	387	347
- technical DDT used (gm)*/	601	706	724	798	767	684
Per capita analyses:						
- cost (NT$)	2.35	2.70	3.05	3.14	2.87	3.22
- surface area sprayed(m^2)	42.4	40.7	44.0	45.0	42.0	40.9
- technical DDT used (gm)*/	83.5	85.4	87.3	89.3	83.3	80.7
Surface area sprayed (m^2) per man-hour labor of spraymen	276.8	215.1	255.9	268.1	262.6	298.0
Percent of time spent for travel against time of operation	32.8	22.4	20.8	18.2	17.1	23.8

*/ DDT used in the spraying program was 75% water dispersible powder.

Decentralized execution and region-wise progression enabled TAMRI, with a small number of staff, to provide intensive, regional training courses and to accomplish strict supervision of field operations. On the other hand, the allotment of a period of only three months a year was sufficient for the local health personnel to participate in the spraying program, while retaining their original jobs for the rest of the year. The work accomplished during the period July 1952 - October 1957 is summarized in Table 31.

Table 31

Summary of Annual Spraying Operations, July 1952 - October 1957

Description	1952	1953	1954	1955	1956	1957
Date started	July 14	March 9	Feb. 15	Mar. 7	Mar. 19	Feb. 7
Date completed	Sept. 28	Nov. 13	Oct. 31	Sept. 27	Dec. 3	Oct. 24
No. of counties involved	2	17	21	21	21	18
No. of townships involved	10	87	262	267	314	151
No. of structures sprayed	21,682	184,653	659,606	630,633	730,468	173,357
Population directly protected	156,217	1,526,306	5,467,664	5,640,325	6,728,465	1,470,156
No. of workers engaged	207	1,763	6,265	6,532	7,694	1,975
Average working days in a region	49.8	50.9	48.2	46.6	44.6	36.2
Insecticides consumed (kg)						
- 75% DDT	12,579	173,707	636,509	670,679	138,330	- - - - - - -
- 68.2% DDT + 0.6% gamma-BHC	- - - - - - -	- - - - - - -	- - - - - - -	- - - - - - -	669,199	173,952
- 6.5% gamma-BHC	- - - - - - -	- - - - - - -	- - - - - - -	- - - - - - -	- - - - - - -	- - - - - - -
-50% DDT	5,671	- - - - - - -	- - - - - - -	- - - - - - -	- - - - - - -	- - - - - - -
Total cost of spraying (NT$)	367,155	4,118,705	16,660,413	17,686,126	19,335,425	4,729,500
Total cost of spraying (US$)	35,646	399,873	1,617,515	1,130,104	780,283	190,859

Among many subject items of importance, cost analysis deserves special attention. Cost of operations as presented here is limited to those expenditures directly related to DDT spraying, excluding administrative overhead, cost for assessment of results and investigational activities. All operational expenditures are summarized by fund sources and further broken down as shown in Table 32.

Table 32

Analyses of Cost of Operations, 1952 - 1956 */

Description	1952	1953	1954	1955	1956
Population protected	156,217	1,526,306	5,467,664	5,640,325	6,728,465
Total cost (NT$) of operations	367,155	4,118,705	16,660,413	17,686,126	19,335,425
% of contribution by fund source					
- township	20.81	37.22	34.34	31.06	35.81
- county	0	0.59	0.85	0.85	0.59
- provincial	2.76	5.75	3.62	9.83	13.08
- ICA, CUSA and JCRR	76.42	56.44	61.19	57.97	50.52
% of cost component					
- DDT	63.54	51.12	56.89	62.40	57.81
- labor	20.81	30.93	27.83	24.35	27.60
- transportation	2.22	3.49	2.39	2.25	2.41
- training	2.20	4.70	3.85	4.16	3.63
- depreciation of equipment and vehicles	1.46	3.45	4.15	2.29	3.07
- supervision	9.22	3.15	1.70	0.97	1.19
- others	0.55	3.16	3.19	3.58	4.29
Cost (NT$) per capita	2.35	2.70	3.05	3.14	2.87

*/ Data for 1957 not available

In analyzing cost of operations, some difficulties were encountered in making the figures comparable from year to year. First of all, the biggest cost component -- DDT -- was obtained from two sources, one imported from the USA and the other manufactured locally. The imported DDT cost less than the locally-manufactured one, if US$ cost was converted into NT$ at the prevailing exchange rate. Therefore

the per capita cost varied greatly depending on the proportion of DDT used from the two different sources. Furthermore, the NT$/US$ conversion rate differed considerably from year to year. Additionally, there was a periodic rise in the cost of labor as well as of other items. For these reasons, the factors listed in Table 33 must be taken into consideration when interpreting the figures shown in Table 32.

Table 33

Factors to be Considered in Interpreting Cost of Operations

Description	1952	1953	1954	1955	1956	1957
Conversion rate (NT$) for US$1.00	10.30	10.30	10.30	15.65	24.78	24.78
Proportion of US DDT vs. local DDT	10:0	7:3	5:5	2:8	0:10	0:10
Average cost of DDT per ton (NT$)	11,700	12,170	14,840	16,520	13,840	
Average wage (NT$) per day per person	10.0	13.2	15.1	14.3	15.6	
Average working days	49.8	50.9	48.2	46.6	44.6	36.2

EPIDEMIOLOGICAL EVALUATION

Annual, Simultaneous Island-Wide Parasite Surveys

To evaluate the effectiveness of the control measure, principally DDT residual house spraying, it was essential to establish an epidemiological baseline before initiating the control operations. There were many data which could be considered; for example, the number of malaria patients seen at the 155 antimalaria stations and in the newly-developed township health stations, positivity rate of blood smears examined, amount of antimalaria drugs consumed, hospital records on malaria patients, etc. Also, there were many epidemiological and entomological data collected by TAMRI through the malaria surveys conducted since 1946. However, all these data were subject to different bias factors making it difficult to compare their relative value between pre- and post-operations.

A clearly unique method used in Taiwan to evaluate the progress of the malaria control program involved "simultaneous parasite surveys" over the island. The idea was the collection, by each of 155 antimalaria stations scattered over the island, of blood smears from 100 pre-school children (between the ages of 2-7) on a single day of the year, December 17, and to repeat the same survey every year in the same localities from children of the same age group on the same day of the year.

This was considered the best way to minimize bias factors and to provide comparable results year after year. These data, along with information from other surveys, provided the base for "Stratification" (see Chapter V).

To organize this extensive survey, TAMRI convened a series of meetings with the technicians of the 144 antimalaria stations in their respective counties during the period December 7-14, 1951. At these meetings, the objectives and method of the simultaneous parasite survey were explained. Each technician was instructed to select a village or villages considered to represent the most malarious area in his township, and to take two sets of 100 blood smears from pre-school children. One set of the 100 smears was to be sent immediately to TAMRI, and the other set to be examined by the technician himself. At these meetings, clean slides, antimalaria drugs, necessary report forms and other supplies were provided. On December 17, 1951 the first survey was carried out and 13,885 blood smears were taken and examined, yielding 1,198 positives (8.63%). The results of the 1951 parasite survey are presented in Table 34, Map 8 and Fig. 64.

Table 34

Island-Wide Simultaneous Malaria Parasite Surveys Among Pre-School Age Children, by Species of Malaria Parasite, 1951 - 1960

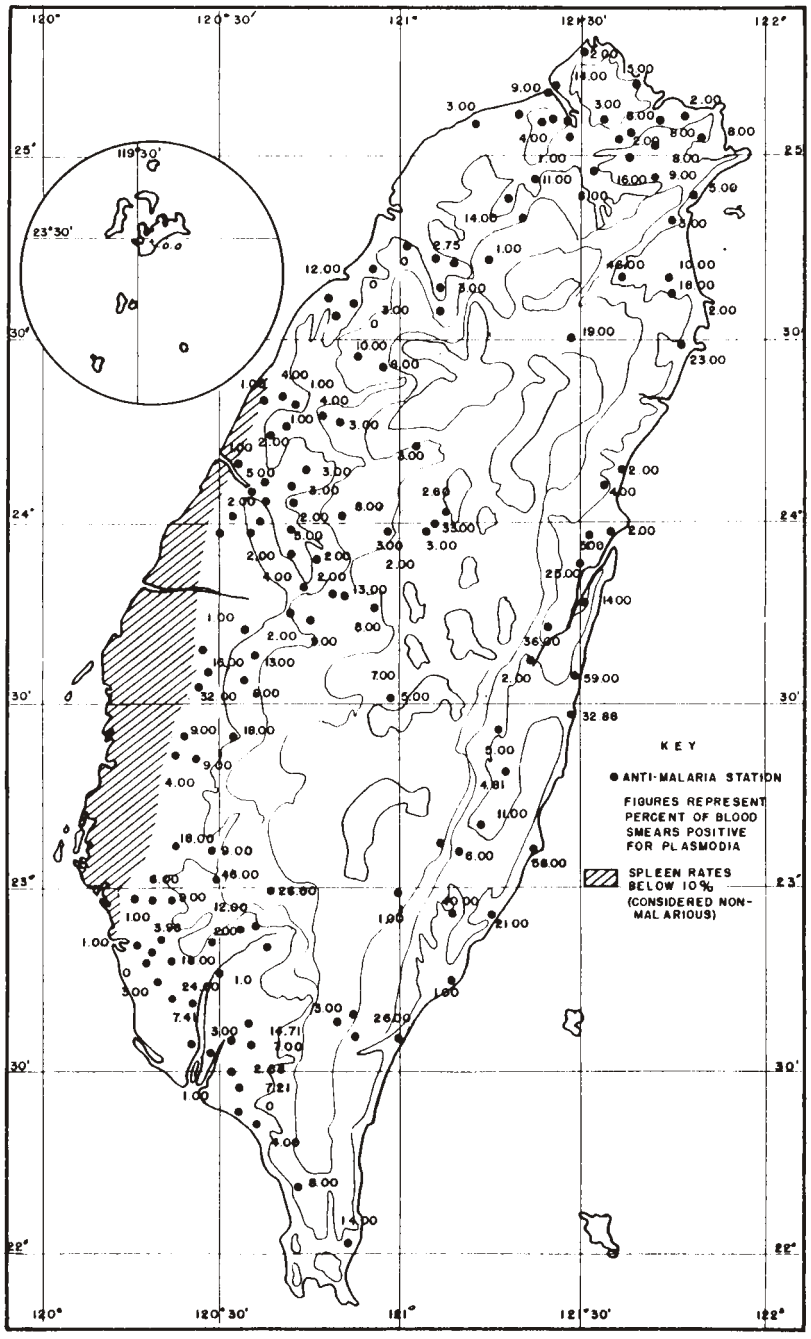
Year	No. of Town-ships	No. of Children Exam.	No. of Positive Cases					Para. Rate (%)	DDT Spraying
			Pv	*Pf*	*Pm*	Mix	Total		
1951	139	13,885	375	669	84	70	1,198	8.63	
1952	143	14,213	532	778	34	41	1,385	9.74	
1953	145	14,419	245	337	46	32	660	4.58	Mar. 9-Nov. 13, 1953
1954	147	14,614	90	68	10	5	173	1.18	Feb. 15-Oct. 31, 1954
1955	148	14,759	12	9	5	4	30	0.20	Mar. 7-Sept. 27, 1955
1956	150	14,825	0	2	0	0	2	0.01	Mar. 19-Dec. 3, 1956
1957	153	15,391	0	0	1	0	1	0.006	Feb. 27-Oct. 24, 1957
1958	153	15,185	0	0	2	0	2	0.013	
1959	148	14,843	0	0	0	0	0	0	
1960	150	15,136	0	0	0	0	0	0	

Pv=P. vivax; Pf=P. falciparum; Pm=P. malariae; Mix=mixed infections.

Note: The surveys were conducted simutaneously throughout the island on December 17 each year.

Map 8

Simultaneous Parasite Survey - December 17, 1951



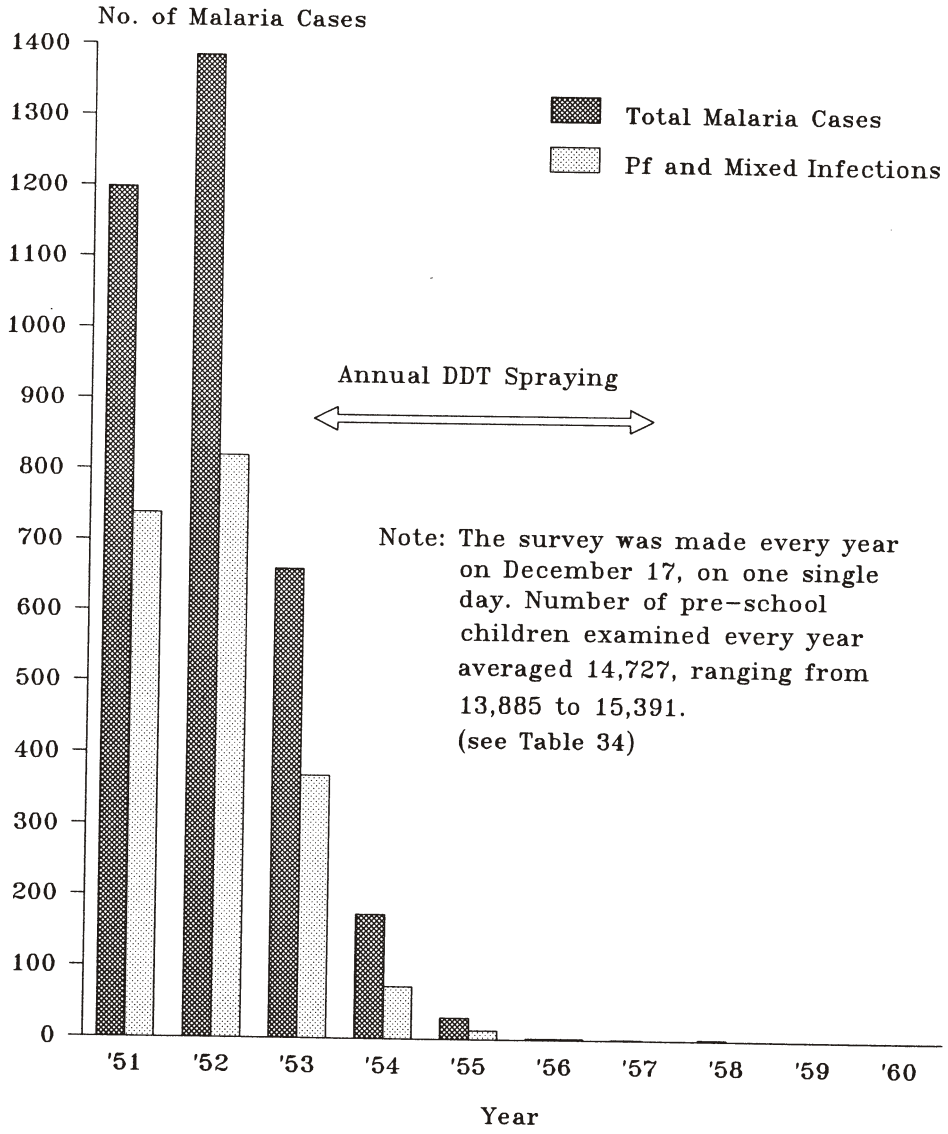


Fig. 64: Island-wide simultaneous malaria parasite surveys among pre-school children, 1951 - 1960

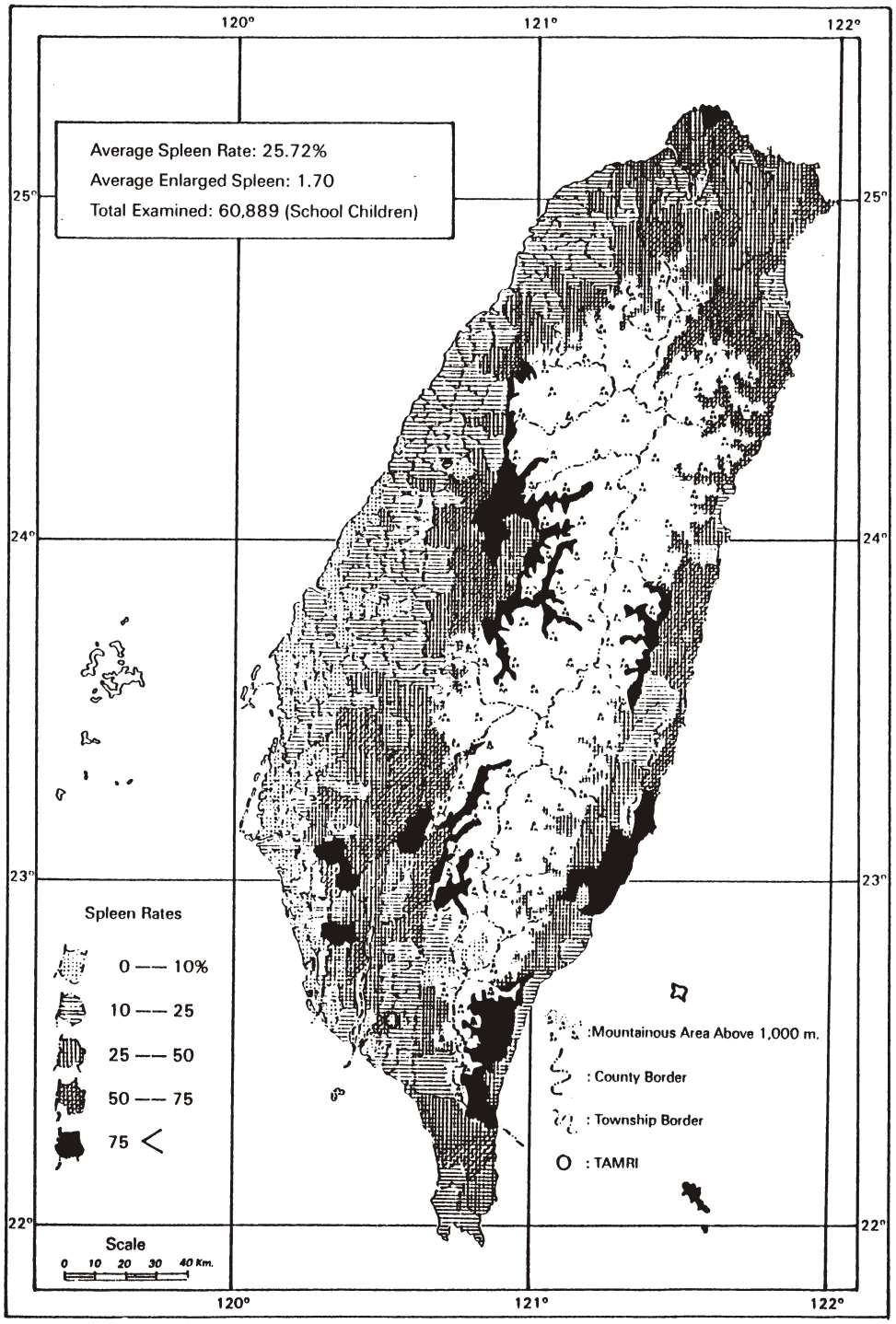
Island-Wide Spleen Surveys

In 1951 many malariometric surveys were made over the island to permit "stratification of malarious areas" in planning the four-year malaria control program. As a result, areas with hyperendemic malaria were defined for inclusion in the 1953 spraying program. At that time, the meso- and hypoendemic areas were generally recognized, but not supported by detailed studies. To more precisely define areas for inclusion in the 1954 and 1955 spraying programs, extensive malariometric surveys were carried out from April to September 1953, involving visits to 582 primary schools on the western plains. At each primary school 200 children, starting from the lowest grade, were examined for splenomegaly; those with an enlarged spleen were further examined for malaria parasites. The age of the children examined ranged from 6 to 12 years, plus a few over 12, but none exceeding 14 years. In total, 103,437 school children were examined and 15,206 were found to have enlarged spleens, with an overall spleen rate of 14.7%. Of the 15,206 examined for malaria parasites, 582 or 3.83%) were found to be positive. In this survey, those schools in the hyperendemic area which had been included in the 1953 spraying program were not visited; therefore both the spleen and parasite rates were rather low. The data obtained through these surveys permitted definition of the 1954 -1955 spraying program which included 257 townships, one special district and sections of five municipalities. The population of these surveyed areas calculated on the basis of household registration up to July 1952 was 5,386,545, exclusive of military personnel.

The results of these malariometric surveys were also regarded as representing baseline malaria endemicity at the initiation of the control program. In order to complete a malaria endemicity map of the whole island, the surveys were further extended to all hyper- to mesoendemic areas, including the aboriginal mountain townships. This extension of the surveys was done from October 1953 through March 1954, covering 264 more primary schools with 43,650 school children. In summary, the island-wide malaria survey effort from April 1953 to March 1954 covered 846 primary schools with 147,087 children. A malaria endemicity map featuring the results of the primary school with the highest spleen rate in each township was prepared for future reference. A total of 358 primary schools was selected to represent the pre-operational malaria indices for the entire island. Exactly the same 358 primary schools were again surveyed during the period July - December 1955. The results of the two surveys are presented in Maps 9 and 10, and Table 35. A spleen survey conducted in a primary school in the Chaochou area is shown in Fig. 65.

Map 9

Pre-Spraying Malaria Endemicity in Taiwan - Spleen Rate of 1953 Survey



Map 10

Post-Spraying Malaria Endemicity in Taiwan - Spleen Rate of 1955 Survey

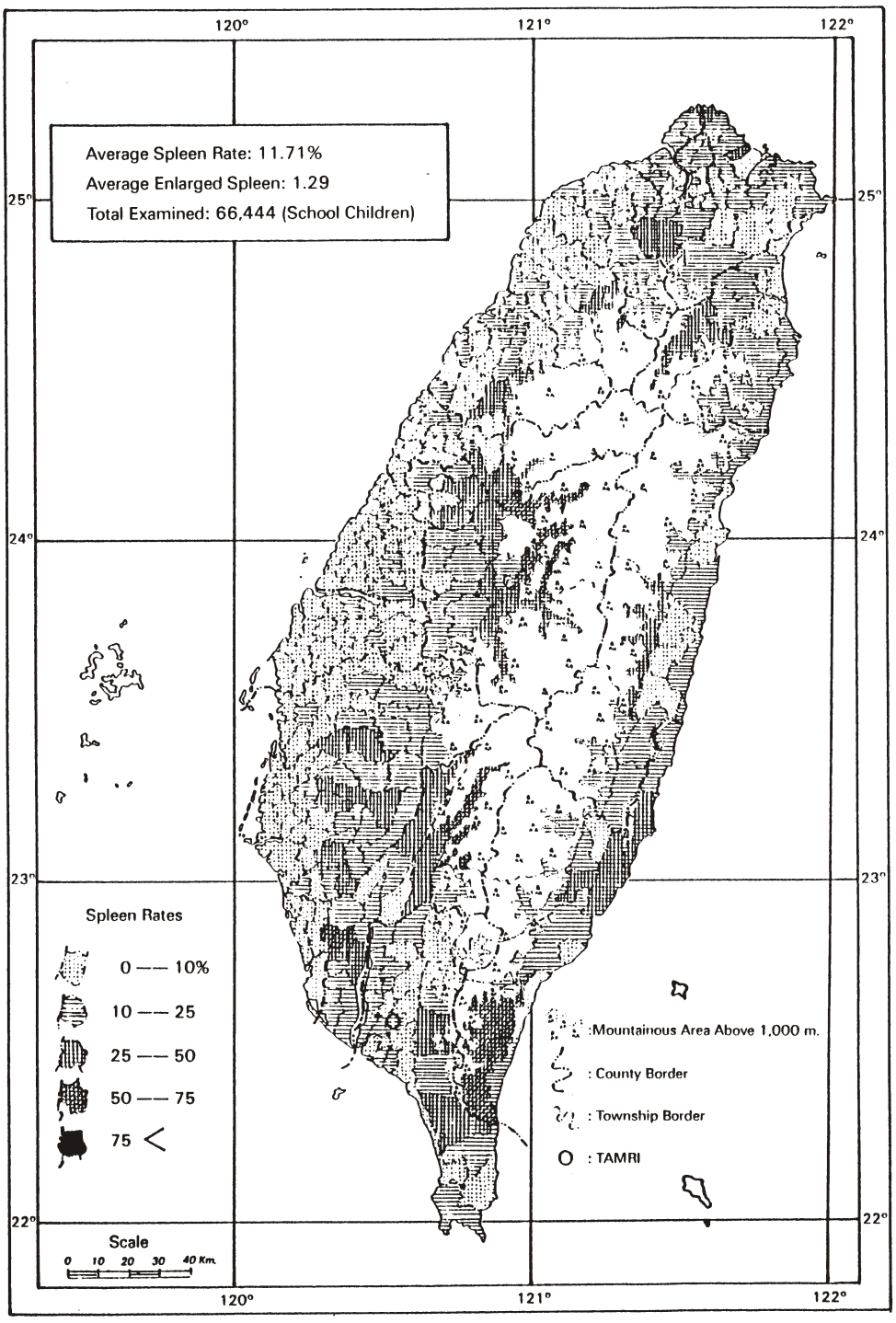


Table 35
Results of the Spleen Surveys, 1953 and 1955

Year	No. Exam.	Spleen Size						Total 1-5	Spleen Rate	AES
		0	1	2	3	4	5			
1953	60,889	45,231	7,387	6,281	1,546	253	191	15,658	25.72	1.70
1955	66,444	58,662	5,735	1,850	185	12	0	7,782	11.71	1.29

Number of schools surveyed = 358
AES = Average enlarged spleen

Fig. 65: Spleen survey of school children
Source: JCRR

Monthly Infant Surveys in Selected Areas

In addition to the Chishan district in southern Taiwan (Chapter VI - Pilot Project), four other areas were selected as indicator districts for monthly infant surveys. These were Taipei county for northern Taiwan, Ilan county for northeastern Taiwan, Taitung county for eastern Taiwan, and Nantou and Taichung counties for central Taiwan. The results of the surveys in all four indicator districts were similar to those obtained in the Chishan district. Infant new infections rapidly disappeared after the first spraying and became completely negative after the second spraying. As an example, the results of the surveys conducted in Nantou and Taichung counties are presented in Table 36. A house-to-house infant survey by a TAMRI technician is shown in Fig. 66.

Table 36

Monthly Infant Parasite Surveys in Nantou and Taichung Counties, December 1952 - June 1954

Survey Period	Selective Spray Area		Complete Spray Area		Check Area	
	No.* Exam.	No. of Positives	No.* Exam.	No. of Positives	No.* Exam.	No. of Positives
Dec. 1952 - May 1953	1,804	58	1,259	36	673	11
	- - - - - - 1st spray completed - - - - - -				- - - no spray- - -	
June - August 1953	1,098	8	635	1	368	1
Sept. - Dec. 1953	1,564	2	796	0	364	11
Jan. - April 1954	1,258	1	626	0	340	5
	- - - - - 2md spray completed - - - - -				- - - 1st spray- - -	
May - June 1954	642	0	327	0	165	1

* "No. Exam." Means the sum total of infants examined during each survey period.

Fig. 66: Monthly infant survey
Source: JCRR

Island-Wide Infant Parasite Survey

The above-mentioned monthly infant surveys were made in the four indicator districts by TAMRI personnel. In addition, local health personnel were requested to take blood smears from infants in their respective areas. Between December 1954 - May 1955, a total of 63,460 blood smears was collected from infants by personnel of 368 health stations and substations. Only eight infants were found to be infected - five with P. falciparum and three with P. vivax. The total estimated number of infants in the entire island was about 350,000; therefore the samples represented approximately 18%. It was very significant that new malaria infections had almost disappeared after two or three annual cycles of DDT spraying.

Entomological Evaluation

Although malariometric and entomologic surveys made during 1952 in the Chishan pilot project gave very convincing and gratifying results, the ten-fold expansion of the DDT spraying operations in 1953 obviously demanded a broader confirmation of the basic strategy. Entomological adult and larval collections were continued in the Chishan district of southern Taiwan, and collection stations were established in four other indicator districts - in Nantou county for central Taiwan, in Taitung county for eastern Taiwan, in Ilan county for northeastern Taiwan, and in Taipei county for northern Taiwan.

Monthly collections in these four indicator districts revealed no significant differences among the four areas. Adult anopheline densities in sprayed premises continued at zero or near-zero levels. On rare occasions when some numbers of anophelines were found in premises recorded as sprayed, the phenomenon could be traced to not-to-be-sprayed microhabitats, such as clothing, to new building materials or repairs, or DDT wipe-off.

In addition to the routine collections made monthly in the indicator districts, mass collections in 50-100 premises were occasionally ordered for non-routine locations. Such collection locations were not completely random in their selection, but the pattern of collections was standardized, i.e. (a) determination of anopheline density about one month after the first DDT spraying; (b) determination of anopheline density about one year after the first DDT spraying; or (c) determination of anopheline density about one month after the second DDT spraying.

With the rarest of exceptions (and reasonable explanations were usually found for those exceptions), these collections as well as those in the indicator districts confirmed the effectiveness of the residual DDT spraying. Table 37 presents the pre- and post-spraying densities of An. minimus and An. sinensis in human habitations and associated cow sheds.

Table 37

Results of Daytime Anopheles Collections
Before and After the Antimalaria DDT Spraying, April 1952 - May 1957

Period of Survey (DDT-Spraying)	April 1952-June 1954 (Before Spraying)		April - May 1957 (5 Sprayings, 1953-57)		April - May 1957 (3 Sprayings, 1954-56)	
Kind of habitat (No. of habitats exam.)	Houses 1,118	Cow Sheds 1,049	Houses 340	Cow Sheds 138	Houses 660	Cow Sheds 275
No. of *An. minimus* (No. per structure)	20,251 (18.11)	8,767 (8.36)	0	1 (0.007)	0	0
No. of *An. sinensis* (No. per structure)	4,127 (3.69)	81,729 (77.91)	41 (0.12)	643 (4.66)	420 (0.64)	8,950 (32.55)

Monthly biological tests were begun in early 1953 in houses in Nantou and Peitou townships in central and northern Taiwan, respectively. The tests were designed for studying: (a) the effectiveness of DDT residues at various intervals after being applied, (b) possible differences in effectiveness of deposits on "plaster" and "mud" surfaces, and (c) insecticidal effectiveness of locally-made DDT compared with DDT imported from the United States.

The data on locally-made DDT were of especial concern because, although samples of each batch from the Kaohsiung factory were being tested in an independent laboratory in the United States, the product was so urgently needed that it was being immediately shipped to the field and used before the test results were being received from the laboratory. To the malaria workers, the results of tests on the walls were more important than those from the laboratory. Generally speaking, no statistically significant difference has been observed between the effectiveness of the local and imported DDT upon either of two surfaces - plaster or mud - upon which the insecticide was applied. On the other hand, both the local and imported DDT proved effective for a shorter period of time when tested on mud than when tested on plaster. Nevertheless, all trials on mud surfaces in Taiwan far exceeded the limited duration of effectiveness for some mud surfaces (or adobe) reported from Mexico - as brief as three months (Downs, Bordas, Navarro, 1951).

Biological tests were run in Taichung to compare the reactions of *An. minimus* to DDT deposits with the reactions of *An. sinensis* to the insecticide, such as in tests used in Peitou and in Nantou. Additionally, tests were run to determine the

minimal period of contact with DDT required to result in high mortalities. Not surprisingly, the more delicate *An. minimus* died more quickly than the robust *An. sinensis* after a given period of contact with the insecticide deposit. Encouragingly, even brief contacts with DDT could result in high mortalities. Contact as short as one-half minute produced 94% mortality of *An. sinensis* when readings were made four hours after contact; when read 24 hours after exposures mortality reached 100%. Collection records for both adult and larval anophelines were filed systematically. As shown on Map 11, virtually no adult *An. minimus* have been found on DDT-sprayed premises. Larvae of *An. minimus* can still be collected in some breeding places in or near sprayed communities, but in very reduced numbers.

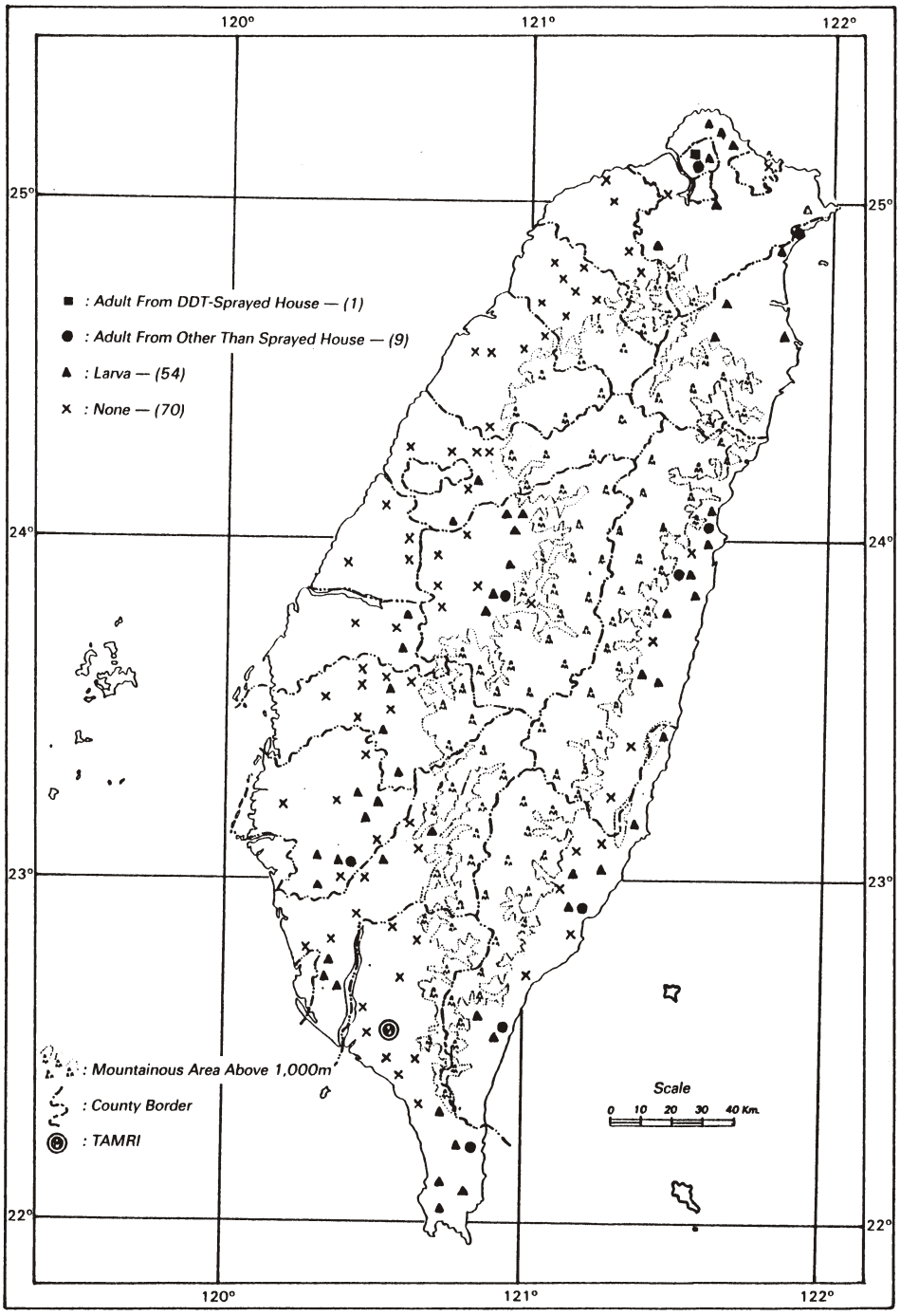
In accordance with the original designation of the international team as the "WHO Malaria and Insect Control Team" both the team and TAMRI counterparts had been receptive to some non-anopheline insect problems associated with the malaria campaign. An example was the survey coverage of Taiwan's *Aedes aegypti* sea and airport information for WHO.

Development of essential arthropod reference collections was begun in 1953, and impressive progress was made as field material accumulated during studies supporting the extended spraying program. Some 100 Cornell-type collection drawers and seven wooden cabinets to house them were made locally for permanent storage of reference specimens.

Mosquito specialist Dr. Alan Stone and colleagues of the Smithsonian Institution in Washington, D.C. enthusiastically received material from Taiwan and provided *bona fide* identifications of the specimens, which were returned for use in the growing TAMRI collection. Their valuable help was very much appreciated.

Map 11

Distribution of An. minimus in Taiwan Based on Surveys from May 1955 - June 1957



PROBLEMS ENCOUNTERED BUT SURMOUNTED

As the DDT spraying coverage was expanded and, according to the stratification strategy, was repeated annually in some originally hyper- and mesoendemic malaria areas, a number of serious problems demanded general or local attention. Examples were bedbug resistance to DDT, silkworm intoxication in sprayed structures, mortality of cats, and spray-associated losses in limited fish culture areas. These and similarly-challenging problems were resolved, but only through investigations which deserve ample description. They will be covered in Chapter XIII under "Special Studies."