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The Secretary of the Expert Committee on Malaria has the honour to communicate hereunder the following note:

SELECTIVE SPRAYING OF PREMISES IN THE CONTROL OF MINIMUS-TRANSMITTED MALARIA IN TAIWAN

by

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(Item 1.2 of the Provisional Agenda)

1. INTRODUCTION

When a four year island-wide malaria control programme was being considered for Taiwan, the parties concerned had at hand much information about the vector, Anopheles minimus, as the result of research by Japanese entomologists and by workers at the Taiwan Provincial Malaria Research Institute. The definitive report by Chow, Liang and Pletsch (1951) furnished further critical information about the vector. It confirmed the use of houses as daytime resting places of A. minimus and revealed marked preferences of these mosquitos for certain locations within the typical house pattern. Intensive house and stable collections of anophelines were continued as a routine part of field investigations when the island-wide project was launched in May, 1952. In making these house-stable collections the entomology technicians carefully recorded the specific room and place within each room for each of the captured specimens.

The typical rural house in Taiwan is rectangular in outline, measuring approximately 5 x 13.5 m. Such a house usually consists of five rooms, including a central sitting room reached through an outside door, two bedrooms flanking the sitting room, and two end rooms commonly serving as kitchen and storeroom. When the number of occupants (from three to 20) overtaxes the two bedrooms, the storeroom may be modified for sleeping purposes. At times the kitchen is also sacrificed for sleeping purposes, and the cooking is done in a smaller lean-to constructed against one end of the house.

The furnishings of the rural homes, described in detail by Chow, Liang, and Pletsch (1951), are very simple. In addition to chairs or benches the most conspicuous items are the elongate ceremonial shelf or table in the sitting-room, the chest of drawers and sleeping platform or bed in the bedroom, and the food cabinet in the kitchen.

The detailed records from anopheline surveys in rural houses indicate a remarkable consistency in the distribution of daytime-resting mosquitos. Approximately 60 per cent. of all Anopheles minimus specimens from houses are captured in bedrooms. The specimens collected from a single category of resting place within the bedrooms - underneath the beds or sleeping platforms - account for about 30 per cent. of all specimens taken indoors. The under surfaces of shelves, tables and other furniture yield from 10 to 15 per cent. of the total anopheline catch. On the other hand the mud or plaster walls of the house, particularly in the sitting-room and kitchen, attract only an occasional specimen. The cowsheds, pig-pens, poultry shelters and other outbuildings sometimes yield tremendous numbers of Anopheles hyrcanus sinensis, but the populations of A. minimus are very low.

The repetitive nature of these distribution patterns suggested the possibility of controlling the vector by selectively spraying only those surfaces of the houses or outbuildings where A. minimus were commonly found. The important questions to be answered were: a) would a partial, selective spraying programme control malaria, and b) would the savings in DDT and labour offset the added difficulties in training spray crews to carry out the modified pattern of coverage?

2. LOCALITIES AND STANDARD PROCEDURES USED IN FIELD TESTS

The initial field operations in the island-wide project were carried out in southern Taiwan during 1952. Field investigations (malariometric and entomological) were concentrated in the operational area of the Chi-Shan District, Kao-Hsiung Hsien, consisting of two valleys separated by high mountains. One valley, with a population of 21,370 persons, served as a check area, and was left unsprayed during 1952. The second valley was divided into two sectors. Structures in one of these sectors, which housed 34,045 people, were sprayed completely. Structures in the other sector,

containing only 2,986 persons, were given selective spraying. Pre-operational spleen, parasite, and infant parasite surveys were carried out during June, 1952. Spraying of the selective and complete spray sectors was accomplished during the period July to September, 1952. Monthly infant parasite surveys, monthly fever case surveys and fortnightly anopheline surveys were initiated; general spleen and parasite surveys among school and pre-school children were carried out at half-year intervals. The second annual spraying coverage of the Chi-Shan District in August-October, 1953, repeated the selective and complete treatment of the respective test areas, and gave the former check area a complete spray treatment.

A more extensive field test of selective spraying was begun in central Taiwan in 1953. Two townships, with a population of 57,705 were given complete spray treatment in March-May, 1953. Nine townships, with a population of 244,770, were given selective spray treatment. Four adjoining townships served as a check area and received no treatment in 1953. In February-April, 1954, the complete and selective spray areas received their second annual treatment, while the former check area was given its first spraying - complete coverage. Spleen, parasite and infant parasite surveys were conducted periodically in the central Taiwan investigational area.

In both the southern Taiwan (Chi-Shan) and the central Taiwan investigational areas, the standard procedure for Complete Spray sectors included the spraying of walls, roofs, ceilings and undersides of furniture in all houses at the rate of 2 g of technical DDT per square metre, applied as a suspension of water-dispersible powder. The inner walls of all outbuildings were sprayed, with the exception of the first half-metre in pig-pens, where the deposit would soon be removed by animal contact. The undersides of roofs of all outbuildings were sprayed.

In the Selective Spray sectors, the standard procedure included in spray coverage is shown in Table I.

Table I: Standard Procedure for Spray Coverage in Selective Spray Sectors

	Bed-room	Store-room	Sitting-room	Kitchen	Toilet	Stables and other outbuildings
Walls	+	+	-	-	+	-
Roof	+	-	-	-	+	-
Ceiling	+	+	-	-	-	-
Ceiling and door of bed canopy, when present	+	-	-	-	-	-
Underside of furniture, and window recesses	+	+	+	only inside and under the food cabinet	-	-
Underside of bed, or bed platform, including walls	+	-	-	-	-	-

All foremen and operators (disinfestors) for the Selective Spray sector were given instruction and intensive field practice in the standard procedures outlined in Table I. Instruction included practice in interpretation of the directions. Thus any room, whether superficially a sitting-room or storeroom or kitchen, or stable, automatically became a bedroom if used by anyone for sleeping purposes. It therefore required the same spray coverage as any other bedroom. Similarly any toilet or latrine, whether indoors or out, received a spraying of walls and roof, for sanitary reasons.

The term "roof" in Table I refers to the under surface of the tile or thatch covering of the house. "Ceiling" refers to the few instances in which rural Taiwanese houses have a horizontal sheathing fastened to the overhead beams. "Ceiling and door of bed canopy" designate the bedroom construction in a few of the wealthier rural homes, where the sleeping platform is built rather elaborately, with sliding doors and with a self-supported bed canopy or false ceiling (in other words, an enclosed bedstead).

The term "window recesses" in Table I refers to the deep window frames formed when openings are cut for windows in the thick mud or brick walls.

The enforcement of the separate protocols for Complete Spray and Selective Spray sectors was simplified by the fact that the spray crews were recruited from local personnel, and were trained in only one of the two standard procedures - either Complete Spray technique or Selective Spray technique - not both.

3. ASSESSMENT OF RESULTS

The effectiveness of the operational activities in southern and central Taiwan was measured by malariometric and entomological field investigations including spleen and parasite surveys, infant parasite surveys, fever case surveys, and anopheline surveys. Data from the south Taiwan investigations will be reviewed first.

Table II presents the spleen and parasite rates in primary school and pre-school children in the Chi-Shan District.

Table II: Spleen and Parasite Rates (School and Pre-school Children), Chi-Shan District

Sector	Survey Month and Year	Spleen Survey			Parasite Survey	
		No.Exam.	Spl.Rate (%)	AES	No.Exam.	Para.Rate (%)
Complete Spray July-Sept.,1952 Aug.-Oct.,1953	June, 1952	1,687	52.28	2.24	1,953	23.04
	Dec., 1952	1,875	31.63	1.96	1,884	11.52
	June, 1953	1,705	24.22	1.87	1,705	5.10
	Dec., 1953	1,823	24.73	1.66	1,830	1.86
	June, 1954	2,071	18.88	1.46	2,277	0.13
Selective Spray July-Sept.,1952 Aug.-Oct.,1953	June, 1952	681	82.95	2.67	762	33.86
	Dec., 1952	682	54.40	1.91	684	17.84
	June, 1953	732	38.25	1.96	730	4.52
	Dec., 1953	738	42.95	1.82	738	2.30
	June, 1954	773	30.14	1.53	870	0.92

Sector	Survey Month and Year	Spleen Survey			Parasite Survey	
		No.Exam.	Spl.Rate (%)	AES	No.Exam.	Para.Rate(%)
Original Check (Complete Spray Aug.-Oct.,1953)	June, 1952	1,419	44.47	1.99	1,452	20.32
	Dec., 1952	1,396	53.58	2.09	1,465	25.73
	June, 1953	1,486	43.47	2.04	1,476	15.79
	Dec., 1953	1,532	38.51	1.90	1,532	8.55
	June, 1954	1,526	26.80	1.63	1,663	2.41

Both Complete Spray and Selective Spray coverage brought about prompt and marked reductions in spleen and parasite rates. The rates found in the June 1954 survey remained higher in the Selective Spray than in the Complete Spray sector, but it will be noted that the original rates were much higher in the former sector.

The effect of complete spraying and selective spraying methods on morbidity rates has been determined by monthly contacts with more than 11,000 persons in the Chi-Shan District. A blood smear is taken from any person who reports a fever during the preceding month, and the malaria rate among these persons is determined from the resultant series of slides. The parasite rates found during the initial fever case survey of July 1952 ran 33.13%, 31.73% and 35.23% for the Complete Spray, Selective Spray, and Check sectors, respectively. The most recent monthly survey in the same sectors (June 1954) showed that the parasite rates among fever cases had dropped to 7.41%, 5.97% and 9.62% after two annual sprayings in the Complete Spray and Selective Spray sectors and one spraying in the original Check sector.

The monthly infant parasite surveys carried out in southern Taiwan (Chi-Shan District) and central Taiwan have included all infants less than 365 days of age at the time of the survey. Any infant found positive is treated and removed from the roster in subsequent surveys. Results from the southern Taiwan infant parasite surveys are shown in Table III.

Table III: Results of Infant Surveys in Southern Taiwan (Chi-Shan District)

Survey Period	Complete Spray Area		Selective Spray Area		Check Area	
	No. Exam.	I.P.R.(%)	No. Exam.	I.P.R.(%)	No. Exam.	I.P.R.(%)
June-Sept. 1952	833	9.60	400	9.50	491	7.94
	.....1st spray completed.....				....no spray....	
Oct. 1952	2,487	.40	1,836	.44	1,997	2.55
Oct. 1953	.....2nd spray completed.....				....1st spray...	
Nov. 1953 June 1954	1,359	.00	1,005	.00	1,252	.08

The sharp initial reduction and subsequent elimination of transmission by two annual sprayings in the Selective Spray as well as the Complete Spray sector have generated confidence in the effectiveness of both types of spraying coverage.

The more severe test of selective spraying in Central Taiwan, where the homes of 244,770 received this type of treatment, has confirmed and augmented the favourable impressions from southern Taiwan. Results of spleen and parasite surveys among school and pre-school children are shown in Table IV.

Table IV: Spleen and Parasite Survey Results (central Taiwan)

Type of Survey	Date of Survey	Complete Spray (sprayed Mar.-May 1953)	Selective Spray (sprayed Mar.-May 1953)	Check Sector
Spleen (6-14 years	Nov. 1952 No.Exam.	1,231	1,625	305
	Spl.Rt.(%)	60.68	63.26	83.28
	Nov. 1953 No.Exam.	1,510	1,882	211
	Spl.Rt.(%)	34.50	44.10	74.30

Type of Survey	Date of Survey		Complete Spray (sprayed Mar.-May,1953)	Selective Spray (sprayed Mar.-May,1953)	Check Sector
Parasite (2-14 years)	Nov.,1952	No.Exam.	565	827	305
		Par.Rt.(%)	13.63	11.85	11.80
	Nov.,1953	No.Exam.	609	921	284
		Par.Rt.(%)	1.15	2.17	8.45

The monthly infant parasite surveys have been carried out in central Taiwan in the same manner as the southern Taiwan surveys. Infants under 365 days of age are included, unless their blood is positive, in which case they are excluded from the roster for subsequent visits. Results are presented in Table V.

Table V: Infant Parasite Rates in Central Taiwan Investigational Areas

Survey Period	Complete Spray sector		Selective Spray sector		Check sector	
	No. Exam.	I.P.R.(%)	No. Exam.	I.P.R;(%)	No. Exam.	I.P.R.(%)
Feb.-May 1953	874	1.95	1,331	2.33	556	1.62
	.....1st spray completed.....				....no spray....	
June-Nov. 1953	1,253	.08	2,290	.44	651	1.08
Dec. 1953-Apr. 1954	804	.00	1,630	.00	421	2.38
	.....2nd spray completed.....				....1st spray...	
May-June 1954	327	.00	642	.00	165	.61

In the sector receiving Complete Spray treatment in March-May 1953, only one positive infant has appeared (July, two months after spraying). In the

Selective Spray sector, positive infants appeared through November (six months after the spraying was finished). However, the Complete Spray sector has yielded no positive infants in the last 11 months and the Selective Spray sector has been negative for seven months. Transmission in the Check sector continued at a high rate until it was given complete spray coverage in February-April 1954.

Intensive monthly searches for anopheline adults have been made in designated house-stable stations in the investigational sectors of southern and central Taiwan. An accurate record has been kept of the specific resting location of any anopheline specimen found in a completely-sprayed, selectively-sprayed, or unsprayed house. Furthermore, the resting locations of specimens in selectively sprayed houses have been tabulated separately for the sprayed and for the unsprayed parts of the houses, as defined in Table I. The results from the south Taiwan and central Taiwan investigational areas are shown in Table VI and VII respectively.

Table VI: Average Numbers of Anopheles Minimus per House Collection (South Taiwan)

Survey Period	Complete Spray Sector	Selective Spray Sector		Check Sector
	Completely sprayed houses	Sprayed parts of houses	Unsprayed Parts of houses	
Aug.-Sept.1952	.00	.00	.00	32.94
	.....1st spraying carried out.....		.....not sprayed.....	
Oct.-Dec.1952	.05	.00	.00	102.62
Jan.-Mar.1953	.21	.00	.13	2.44
Apr.-July 1953	.11	.00	.07	9.94
Aug.-Oct.1953	.00	.00	.00	.04
	.....2nd spraying carried out.....		...no spray..	..1st spraying
Nov. 1953 Jan. 1954	.00	.00	.00	.00
Feb.-Apr.1954	.00	.00	.00	.00
May-July 1954	.00	.00	.00	.00

Table VII: Average Numbers of Anopheles Minimus per House Collection (Central Taiwan)

Survey Period	Complete Spray Sector	Selective Spray Sector		Check Sector
	Completely sprayed houses	Sprayed parts of houses	Unsprayed Parts of houses	
Mar.-May 1953	.00	.00	.00	4.75
	.....1st spraying carried out....		.....not sprayed.....	
June-Sept.1953	.00	.13	.29	7.94
Oct.-Jan.1954	.00	.00	.00	3.23
Feb.-Apr.1954	.00	.00	.00	.35
	.....2nd spraying carried out....		.....not sprayed 1st spraying	
May-July 1954	.00	.00	.00	.00

The complete spraying of houses in the Complete Spray sector and the spraying of preferred resting locations in the Selective Spray sector houses reduced the A. minimus index to zero or near zero. Moreover, the A. minimus index for the unsprayed portion of the Selective Spray houses was also brought to the zero or near-zero mark. Continued studies and analyses are being made of the indoor resting habits of A. minimus, and will be reported in a separate paper. It may be stated in summary, however, that there is no evidence that the spraying of the originally preferred indoor resting places has resulted in any noticeable shift of A. minimus to other indoor locations not formerly used for daytime resting.

4. COMPARATIVE COSTS OF COMPLETE AND SELECTIVE SPRAYING

The WHO public-health engineer, Mr. P.S. Echavez, and counterpart personnel in the Malaria Institute have analysed the 1953 operational costs in central Taiwan, where 261,462 people were directly protected by Complete Spray techniques (57,705 people inside, and 203,757 persons outside, the investigational areas). The population under direct protection by Selective Spray technique in central Taiwan totalled 244,770. The detailed analyses will be reported by field

operational personnel in another paper, but the engineering group has kindly released the gross figures on comparative per capita costs and areas sprayed, as shown in Table VIII.

Table VIII: Comparative Areas sprayed and Operational Costs for the Complete and Selective Spraying Areas in Central Taiwan

	Completely Sprayed	Selectively Sprayed	Savings Through Selective Spraying
Area sprayed/capita	43.38 m^2	26.72 m^2	16.66 m^2 (38.4%)
Cost in US$/capita*	$ 0.180	$ 0.134	$ 0.046 (25.6%)

* At official rate, NT$ 15.60 equals US$1.00. The cost analysis included all local (township and prefectural) costs, insecticides, depreciation on sprayers and vehicles, plus cost of Malaria Institute administration and engineering section supervision associated with field operations. Not included were the overhead costs of malariometric and entomological investigations, nor the gross Malaria Institute overhead.

5. DISADVANTAGES OF SELECTIVE SPRAYING

Despite the obvious savings in programme costs, there are several aspects of selective spraying which militate against its unqualified adoption throughout Taiwan. Continued intensive observations on A. minimus population in the unsprayed cowsheds (stables) of the Selective Spray sectors are being considered in a separate paper, but may be mentioned briefly here. Populations of A. minimus in Selective Spray sector stables drop far below those in unsprayed check areas, but they do not approach the zero mark, as in the Complete Spray sector. Whether the remaining low populations of A. minimus in the Selective Spray cowsheds may encourage development of insecticide-resistant forms is not known, but the possibility cannot be ignored. Precipitin tests should be accomplished to determine whether the remaining stable-harboured A. minimus are feeding predominantly on human blood, or whether they represent a physiologic form associated with cattle.

The attitude of the farmers in Selective Spray sector represents a more vocal argument against this type of coverage. Unsprayed stables continue to

harbour sizeable populations of Anopheles hyrcanus sinensis which annoy the water buffalo (proof of A.h.sinensis involvement in local malaria transmission is still lacking). The average farmer in Taiwan looks with question on any programme which protects the human elements of his family while ignoring his valuable and faithful beast of burden. Residents in several Selective Spray townships have requested Complete Spray coverage, and one township has even volunteered to pay for the extra DDT from township funds!

Lastly, there is an adverse psychological effect when a spray crew, however systematically trained and supervised, enters a premise and accomplishes what seems, to the householder, a less than complete job. This impression persists despite attempts to educate the householders, and has resulted in reports that the spraymen were "doing careless work" and "forgetting parts of the house". This human tendency, along with other factors mentioned above, has somewhat tempered our enthusiasm for island-wide adoption of selective spraying, despite its demonstrated effectiveness.

6. SUMMARY

1. Based upon intensive studies of daytime resting habits of Anopheles minimus, the houses in large areas in southern and central Taiwan were sprayed selectively, omitting from the spray coverage those parts of the premises which seldom, if ever, harboured significant numbers of the vector.

2. Emphasis in spray pattern was on bedrooms, storerooms, and the undersides of furniture in sitting-rooms and kitchens. No spraying of sitting-room or kitchen walls was carried out. Stables were not sprayed.

3. Houses in adjoining areas were sprayed conventionally (completely) or left unsprayed as checks.

4. The data from spleen and parasite surveys and infant parasite surveys in the two investigational areas, plus fever case surveys in the southern Taiwan studies indicated effective control of malaria transmission by the Complete Spray methods, and parallel results when the Selective Spray technique was employed.

5. Intensive periodic house-collections of Anopheles in both study areas showed that populations of A. minimus dropped to the zero or near-zero level

in houses in the Complete Spray sector and in the sprayed parts of houses in the Selective Spray sector. Furthermore, anopheline populations in unsprayed portions of the Selective Spray sector houses showed the same decline, indicating that daytime resting habits were not undergoing detectable changes in the Selective Spray sector.

6. The number of square metres per capita requiring spraying in the Selective spray sector of central Taiwan was 38.4% less than in the Complete Spray sector. The cost in US$ per capita was $0.180 in the Complete Spray sector and $0.134 in the Selective Spray sector - a saving of 25.6%.

7. Disadvantages of the selective spraying procedure include the unknown resistance-developing effect of the anopheline populations remaining in unsprayed stables, the disappointment of farmers whose water buffalo receive no protection in the stable, and the psychological effect of doing a less than complete spray job which may be misinterpreted by householders as carelessness on the part of the spray crews.

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