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Filarial Infection in Vector Mosquitos after Mass Drug Administration in Western Samoa

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ABSTRACT: In order to control filariasis in Western Samoa, the first round of mass administration of diethylcarbamazine was carried out during 1965−1966, without undertaking any vector control measures. Four years of post-control entomological evaluation has revealed that the infection rate has dropped from 8.35% to 0.61% (1/14 of pre-control rate) in *Aedes (Stegomyia) polynesiensis* and 4.47% to 0.26% (1/17 of pre-control rate) in *Aedes (Finlaya) samoanus*; and the infective rate has dropped from 2.95% to 0.070% (1/42 of pre-control rate) in *Ae. polynesiensis* and 0.26% to 0 in *Ae. samoanus*. More reduction was observed in the infective rate than the infection rate, presumably because of a remarkable decrease in the number of filarial larvae in infected mosquitos. It is suggested that, for the entomological evaluation of filariasis control, the infective rate should be preferred to the infection rate. Of the three infective *Ae. polynesiensis* detected after the campaign, one was found three months after its completion and the other two at least 3−1/2 years later. No difference has been observed in the infection rate in mosquitos between different geographical locations. The drug distribution coverage was significantly less in the districts with infected mosquitos than in those where no infected mosquitos were found.

Western Samoa consists of a group of tropical islands in the South Pacific, with a population of about 140,000. The main islands are Upolu, which is the smaller but more densely populated, and Savai'i, the larger but less populated. These two islands are divided into 15 health districts.

The country is one of the endemic areas of subperiodic bancroftian filariasis, which is common in most parts of the South Pacific. The vectors of filariasis in Western Samoa are *Aedes (Stegomyia) polynesiensis*, *Ae. (S.) upolensis* and *Ae. (Finlaya) samoanus* (Iyenger, 1961; Ramalingam & Belkin, 1964; Ramalingam, 1968). *Ae. polynesiensis*, a common vactor of subperiodic bancroftian filariasis throughout the South Pacific, is found in fairly high density almost everywhere in Western Samoa. *Ae. upolensis* is a forest mosquito, occurring only in Western Samoa. Although *Ae. upolensis* is frequently found infected (Ramalingam & Belkin,

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1964), its role in the transmission of filariasis seems doubtful, because few have been collected on human bait in and around villages. *Ae. samoanus* has been found only in Western and American Samoa (Belkin, 1962; Ramalingam, 1968). where it is not so evenly distributed as *Ae. polynesiensis* but is abundant in the mountains and along the coast close to forests.

In order to control filariasis in Western Samoa, the first round of mass drug administration covering the whole country was carried out during the period August 1965 to September 1966. The drug used was diethylcarbamazine at the dose of 5 mg per kg of body weight, once a week for six weeks, followed by once a month for 12 months. From July 1967 to the second half of 1968, residual positive cases, detected by blood survey, received additional doses of the drug. The control programme included only drug administration, without any vector control measures.

This paper deals with the infection rate in the two main vectors, *Ae. polynesiensis* and *Ae. samoanus*, and its relationship to the completeness of the drug coverage. The study was made during the period December 1966 to December 1970, after the completion of the first round of mass drug administration.[1]

METHODS

Mosquitos landing on the human bait were caught with a sucking tube. Catches were made in the day-time, mainly for *Ae. polynesiensis*, and at night, mainly for *Ae. samoanus*, both inside and outside the houses.

The mosquitos caught were brought to the laboratory, identified and dissected as soon as possible, or, if immediate dissection was not possible, they were preserved in an alcohol-glycerine mixture and dissected later. The number of first, second and third (mature) stage larvae of *Wuchereria bancrofti* was recorded. Mosquitos with microfilariae only were disregarded. Those carrying larvae at any stage were recorded as "infected" i.e. infection rate, and those with third (mature) stage larvae as "infective".

During the survey, 4,290 *Ae. polynesiensis* and 1,148 *Ae. samoanus* were dissected and examined for filarial infection. In addition, 100 *Ae. tutuilae*, 57 *Ae. oceanicus*, 22 *Ae. aegypti* and 45 *Culex pipiens fatigans* were dissected, but none of these was infected.

RESULTS

Pre-control infection rate

The infection rates in mosquitos obtained in 1963 by Ramalingam (1968) were considered as the pre-control baseline data. The 1963 infection and infective rates in *Ae. polynesiensis* were 8.35% and 2.95%, respectively; and in *Ae. samoanus* 4.47% and 0.26%. (See Table 1).

[1] The second round of mass drug administration was started in January 1971 and completed by the end of the year. The dosage scheme was 6 mg/kg body weight at monthly intervals for 12 doses. The blood survey carried out a few months after completion of this second round revealed a microfilaria rate of 0.19%.

Reduction of the infection rate

The dissection records for each year from 1966 to 1970 are summarized in Table 1.

The infection rate in *Ae. polynesiensis* decreased year by year, i.e. 0.71% in 1966 −1967, 0.64% in 1968, 0.46% in 1969, and 0.35% in 1970, and the overall rate was 0.61%. which is about 1/14 of the pre-control rate. Infective *Ae. polynesiensis* were found in 1966 and 1970. The overall infective rate was 0.07%, which is about 1/42 of the pre-control rate.

The infection rate for 1966-1970 in *Ae. samoanus* was 0.26%, which is about 1/17 of the pre-control rate. No infective *Ae.samoanus* were found after the mass drug administration.

Table 1. Infection rate in mosquitos before and after the first round of mass drug administration in Western Samoa

Species/Year	No. of mosquitos dissected	Infection rate (all larval stages)			Infective rate (third-stage larvae)		
		No. of mospuitos positive	% positive	No. of larvae found	No. of mosquitos positive	% positive	No. of larvae found
Ae. polynesiensis							
Before mass drug control							
1963[a]	407	34	8.35	−	12	2.95	−
After mass drug control							
1966−1967[b]	2,381	17	0.71	39	1	0.042	1
1968	466	3	0.64	5	0	0	0
1969	865	4	0.46	5	0	0	0
1970	578	2	0.35	3	2	0.35	3
Total	4,290	26	0.61	52	3	0.070	4
Ae. samoanus							
Before mass drug control							
1963[a]	380	17	4.47	−	1	0.26	−
After mass drug control							
1966−1967[b]	98	2	2.04	2	0	0	0
1968	80	0	0	0	0	0	0
1969	9	0	0	0	0	0	0
1970	961	1	0.10	1	0	0	0
Total	1,148	3	0.26	3	0	0	0

a Cited from Ramalingam (1968).

b For 1966, dissection was made from 16 December to the end of the year.

Reappearance of infected and infective mosquitos

During the post-control survey, infected mosquitos were found in seven districts in Upolu Island. Infected *Ae. polynesiensis* (Table 2a) were found in all seven, infective *Ae. polynesiensis* in three, and infected *Ae. samoanus* (Table 2b) in two of the districts. No infective *Ae. samoanus* were found, nor were any infected mosquitos found on Savai'i Island.

Infected *Ae. polynesiensis* (Table 2a) were found in 23 out of 140 villages surveyed (16.4%) and infective ones in 3 (2.1%). Infected *Ae. samoanus* (Table 2b) were found in

3 out of 46 villages surveyed (6.5%).

Table 2. Infection and infective rates of mosquitos and number of villages with infected or infective mosquitos in each district after the campaign

(a) *Ae. polynesiensis*

Island/District	Mosquitos			Villages		
	No. dissected	No. infected	No. infective	No. surveyed	No. with infected mosquitos	No. with infective mosquitos
Upolu Island						
Northwest districts						
Apia	1,932	12	1	54	11	1
Leulomoega	264	2	0	10	2	0
Falelatai	379	2	0	11	2	0
Fagaloa	86	1	1	2	1	1
Lufilufi	727	7	1	11	5	1
Sub-total	3,388	24 (0.71%)	3 (0.089%)	88	21 (23.9%)	3 (3.4%)
Southeast districts						
Lefaga	145	0	0	6	0	0
Safata	177	1	0	8	1	0
Falealili	206	1	0	12	1	0
Aleipata	205	0	0	7	0	0
Sub-total	733	2 (0.27%)	0 (0%)	33	2 (6.1%)	0 (0%)
Total for Upolu	4,121	26 (0.63%)	3 (0.073%)	121	23 (19.0%)	3 (2.5%)
Savai'i Island						
Faasalelaga	17	0	0	2	0	0
Fagamalo	23	0	0	3	0	0
Safotu	21	0	0	2	0	0
Sataua	55	0	0	6	0	0
Salaiiua	29	0	0	4	0	0
Satupaitea	24	0	0	2	0	0
Total for Savai'i	169	0 (0%)	0 (0%)	19	0 (0%)	0 (0%)
Grand total	4,290	26 (0.61%)	3 (0.070%)	140	23 (16.4%)	3 (2.1%)

Influence of completeness of drug distribution coverage on the mosquito infection rate

It is probable that in villages where drug distribution was incomplete more people continued to carry microfilariae, and this caused a higher infection rate in mosquitos. To test this the relation between the coverage and the infection rate was examined.

Three indices were introduced to represent the coverage: "population coverage", the percentage of people who took one dose or more of the drug; "dosage consumption", the ratio of the number of doses actually taken to total doses which should have been taken (population × 18); and "complete dose coverage," the ratio of the people who took the full 18 doses to the entire population. These indices are shown for all districts except Apia in Table 3.

Table 2. (continued) (b) *Ae. samoanus*

Island/District	Mosquitos			Villages		
	No. dissected	No. infected	No. infective	No. surveyed	No. with infected mosquitos	No. with infective mosquitos
Upolu Island						
Northwest districts						
Apia	278	0	0	14	0	0
Leulomoega	1	0	0	1	0	0
Falelatai	24	2	0	2	2	0
Fagaloa	0	0	0	0	0	0
Lufilufi	170	1	0	3	1	0
Sub-total	473	3 (0.63%)	0 (0%)	20	3 (15.0%)	0 (0%)
Southeast districts						
Lefaga	105	0	0	7	0	0
Safata	150	0	0	4	0	0
Falealili	2	0	0	1	0	0
Aleipata	15	0	0	1	0	0
Sub-total	272	0 (0%)	0 (0%)	13	0 (0%)	0 (0%)
Total for Upolu	745	3 (0.4%)	0 (0%)	33	3 (9.1%)	0 (0%)
Savai' i Island						
Faasaleleaga	30	0	0	1	0	0
Fagamalo	97	0	0	2	0	0
Safotu	67	0	0	2	0	0
Sataua	10	0	0	1	0	0
Salailua	83	0	0	4	0	0
Satupaitea	116	0	0	3	0	0
Total for Savai' i	403	0 (0%)	0 (0%)	13	0 (0%)	0 (0%)
Grand total	1,148	3 (0.26%)	0 (0%)	46	3 (6.5%)	0 (0%)

Coverage and infection rate in different areas

The 14 districts were divided into three areas, North-west Upolu, South-east Upolu and Savai'i Island.

As seen in Table 4, the infection rate in *Ae. polynesiensis* was highest in North-west Upolu, next in South-east Upolu and lowest in Savai'i. Population coverage was in the reverse order, i.e. lowest in North-west Upolu, next in South-east Upolu and highest in Savai'i. Dosage consumption and complete dose coverage were, however, lowest in South-east Upolu, next in North-west Upolu and highest in Savai'i.

Coverage in areas positive and negative for infected mosquitos

The 14 districts were divided into two group: the six districts in which infected mos-

Table 3. Coverage of drug distribution in district in the each first round of mass drug administration in Western Samoa[1]

Island/District	Population	Population coverage (%)	Dosage consumption (%)	Complete doses coverage (%)
Upolu Island				
Northwest districts				
Leulumoega‡	9,380	92.57	71.00	26.55
Falelatai‡	5,646	89.50	62.17	7.35
Fagaloa‡	1,503	94.74	74.89	10.78
Lufilufi‡	5,306	93.78	67.67	23.05
Southeast districts				
Lefaga	1,258	94.52	77.91	57.71
Safata‡	3,950	96.08	58.85	0
Falealili‡	6,237	95.22	62.55	0
Aleipata	1,700	97.24	69.06	22.88
Savai'i Island				
Faasaleleaga	7,211	95.16	68.89	10.73
Fagamalo	2,066	96.18	79.08	21.49
Safotu	5,127	96.18	76.65	40.37
Sataua	4,487	98.04	78.79	14.75
Salailua	5,125	99.65	79.51	34.03
Satupaitea	6,800	96.84	78.14	44.00
Total	65,796	95.12	71.01	21.42

[1] Data not available for Apia district.
‡ District with infected mosquitos.

Table 4. Coverage of drug distrbution and the infection and infective rates in mosquitos after the campaign in different areas

Area	Coverage			Infectivity					
				Ae. polynesiensis			*Ae. samoanus*		
	Population coverage (%)	Dosage consumption (%)	Complete dose coverage (%)	No. dissected	No. infected	No. infective	No. dissected	No. infected	No. infective
Geographical areas									
North-west Upolu Island‡	92.22	68.18	19.65	1,456	12 (0.82%)	2 (0.14%)	195	3 (1.54%)	0 (0%)
South-esat Uplu Island	95.67	63.75	8.48	733	2 (0.27%)	0 (0%)	272	0 (0%)	0 (0%)
Savai'i Island	96.93	76.11	82.19	169	0 (0%)	0 (0%)	403	0 (0%)	0 (0%)
Areas of different infectivity									
Districts with infected mosquitos‡	93.28	65.93	13.40	1,839	14 (0.76%)	2 (0.11%)	347	3 (0.86%)	0 (0%)
Districts with no infected mosquitos	96.86	75.83	29.02	519	0 (0%)	0 (0%)	523	0 (0%)	0 (0%)
All of Western Samoa excluding Apia district									
14 districts	95.12	71.01	21.42	2,358	14 (0.59%)	2 (0.085%)	870	3 (0.34%)	0 (0%)

‡ Excluding Apia district.

Table 5. Results of significance tests

Item	Difference				Significance test: Probability	Significance test: Significant or non-significant
Infectivity rate between *Ae. polynesiensis* and *Ae. samoanus* in pre-control phase						
Rate of the infecteds	*Ae. polynesiensis* (8.35%)	>	*Ae. samoanus* (4.47%)		0.019	Significant
Rate of the infectives	*Ae. polynesiensis* (2.95%)	>	*Ae. samoanus* (0.26%)		0.004	Highly significant
Ratio: infectives/infecteds	*Ae. polynesiensis* (12/34)	>	*Ae. samoanus* (1/17)		0.037	Significant
Reduction of infectivity rate in *Ae. polynesiensis* by mass drug administration						
Rate of the infecteds	Pre-control (8.35%)	>	Post-control (0.16%)	<	0.00003	Highly significant
Rate of the infectives	Pre-control (2.95%)	>	Post-control (0.070%)	<	0.00003	Highly significant
Ratio: infectives/infecteds	Pre-control (12/34)	>	Post-control (3/26)		0.035	Significant
Reduction of infectivity rate in *Ae. samoanus* by mass drug administration						
Rate of the infecteds	Pre-control (4.47%)	>	Post-control (0.26%)	<	0.00003	Highly significant
Rate of the infectives	Pre-control (0.26%)	>	Post-control (0%)		0.28	Non-significant
Geographical distribution of infected mosquitos in post-control phase						
Ae. polynesiensis	Upolu Island (0.63%)	>	Savai' i Island (0%)		0.245	Non-significant
Ae. samoanus	Upolu Island (0.40%)	>	Savai' i Island (0%)		0.252	Non-significant
Ae. polynesiensis	NW-Upolu Is. (0.71%)	>	SE Upolu Is. (0.27%)		0.137	Non-significant
Ae. samonus	NW-Upolu Is. (0.63%)	>	SE-Upolu Is. (0%)		0.237	Non-significant
Treatment coverage in areas positive and negative for infected mosquitos						
Population coverage	Negative group (96.86%)	>	Positive group (93.28%)	>	0.00003	Highly significant
Dosage consumption	Negative group (75.83%)	>	Positive group (65.93%)	>	0.00003	Highly significant
Complete dose covrage	Negative group (29.02%)	>	Positive group (13.40%)	>	0.00003	Highly significant
Comparison of infectiviy rate for areas positive and negative for infected mosquitos after the campaign						
Rate in *Ae. polynesiensis*	Positive group (0.76%)	>	Negative group (0%)		0.038	Significant

quitos were found, and the eight districts in which no infected mosquitos were found. Any one of the indices of the coverage was far lower in the positive group than in the negative group (Table 4), and the difference in the infection rate in *Ae. polynesiensis* between the positive and the negative areas was significant (Table 5, last row).

DISCUSSION

Vectorial efficiency of Ae. polynesiensis and Ae. samoanus

A study of the infection rates presented by Ramalingam (1968) shows that, before control: (1) the infection rate was significantly higher in *Ae. polynesiensis* (8.35%) than in *Ae. samoanus* (4.47%); (2) the infective rate was highly significantly greater in *Ae. polynesiensis* (2.95%) than in *Ae. samoanus* (0.26%); and (3) the ratio of the infective rate to the infection rate was significantly higher in *Ae. polynesiensis* (1/2.8) than in *Ae. samoanus* (1/17) (Table 5). In other words, there was one infective mosquito for each 2.8 infected *Ae. polynesiensis*, while as many as 17 *Ae. samoanus* were infected for each one infective.

This supports the assumption that *Ae. polynesiensis* is more efficient than *Ae. samoanus* in transmitting filariasis in Western Samoa; but other studies such as experimental infection, are needed to prove this assumption. The ratio of the infective to infection rates in any mosquito species caught in an endemic area of filariasis could be a valuable index of vectorial efficiency.

Greater reduction in infective mosquitos than infected mosquitos

The differences between pre-control and post-control infection rates are highly significant, except for the infective rate in *Ae. samoanus*, whichwas very low to begin with (Table 5).

The pre-control ratio of the infective to the infection rates in *Ae. polynesiensis* is 1: 2.8, which is significantly higher than the post-control ratio of 1: 8.7. This means that to produce one infective *Ae. polynesicnsis*, only 2.8 infected mosquitos are needed in the pre-control phase, while as many as 8.7 infected mosquitos are needed in the post-control phase.

Since this campaign used only mass drug administration and no vector control measures, no change could be expected in the ecology of the mosquito population or of an individual mosquito, e. g., the density, longevity, fecundity, even after the impact of the drug on filarial parasites in humans. A possible cause of the greater reduction in the infective rate than in the infection rate, is the decrease in the number of filarial larvae infecting mosquitos, due to the decreased microfilaria density in human blood. The average number of all stage larvae per infected *Ae. polynesiensis* is 2.0 in the post-control phase; this figure is presumably much lower than that in the pre-control phase, although the corresponding data are not available.

It is suggested that, for the evluation of filariasis control, the infective rate of mosquitos should be preferred to the infection rate.

Reappearance of infective mosquitos

The first one of the three infective *Ae. polynesiensis* in the post-control survey was found in 1966, only three months after the completion of the mass drug administration. Thereafter, no infective mosquitos were found for more than three years. It should be noted that, from July 1967 to the second half of 1968, residual positive persons detected in blood surveys were treated by drug administration on a daily basis. The early reappearance of the first infective mosquito is probably due to the residual positive cases.

The other two infective mosquitos were found at least 3−1/2 years after the completion of the mass drug administration.

Location of infected and infective mosquitos

Although in Table 4 the infection rate seems higher in Upolu Island than in Savai'i Island, and higher in the North-west than in the South-east of Upolu, statistical analysis of the results (Table 5) shows that three is no significant difference in the infection rate in either species of mosquito (*Ae. polynesiensis* and *Ae. samoanus*) among the different geographical areas.

Coverage of drug distribution and mosquito infection rates

Table 5 shows that the coverage of drug distribution is significantly lower in the districts with infected mosquitos than in those where no infected mosquitos were found. The highest coverage in a district in which infected mosquitos were found was: 96.08% for the population coverage, 74.89% for the dosage consumption and 26.55% for the complete dose coverage.

It is hoped that the threshold level of drug distribution coverage, beyond which no infected mosquitos would be expected, can be established through more thorough surveys on mosquito infection after the second round of mass drug administration in Western Samoa.

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西サモアの全住民に対するジエチルカルバマジン投与後の媒介蚊のフィラリア感染率

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亜周期性バンクロフト糸状虫によるフィラリア浸淫地の一つである南太平洋の西サモアで，ジエチルカルバマジンを全人口に投与する方法によって，1965–66年に広範な駆除が実施された．ただし媒介蚊の駆除は全く行なわれていない．その後4年間に及ぶ調査の結果，媒介蚊の感染率（各期幼虫を含む）は，*Aedes* (*Stegomyia*) *polynesiensis* では，実施前の8.35%から，実施後には0.61%（約1/14）にまで減少した．また *Aedes* (*Finlaya*) *samoanus* では，4.47%から0.26%（約1/17）に減少した．感染期幼虫の感染率は，*Ae. polynesiensis* で2.95%から0.070%（1/42）に，*Ae. samoanus* では，0.26%から0に減少した．各期幼虫感染率の減少よりも，感染期幼虫感染率の減少がいちじるしいのは，感染蚊中の幼虫数の極度の減少によるものと思われる．フィラリア駆除の昆虫学的効果判定は，感染期幼虫感染率によることがのぞましい．駆除実施後に見出された，感染期幼虫をもつ3個体の *Ae. polynesiensis* のうち，1個体は駆除終了の3カ月後に，また他の2個体は，少なくとも3.5年後に採集されたものである．西サモアの各地域の間では，蚊の感染率に顕著な差はみとめられなかった．ただ，感染蚊が見出された地域では，見出されなかった地域に比較して，ジエチルカルバマジンの摂取は有意に少なかった．

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