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Dengue Vector Surveillance and Control in Taiwan

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Abstract: In view of possible dengue outbreak due to the rapid development of national tourism to Southeast Asia, the long-neglected *Aedes* surveillance was resumed since July 1987. After the dengue outbreak was detected in November 1987, the surveillance was greatly intensified, and house mosquitoes were collected for virus isolation. Nine isolates of dengue type one virus were obtained from the female mosquitoes of *Aedes aegypti* among the 9 species of mosquitoes collected in houses in 1987 and 1988. Health education of the public was enforced by propaganda through newspapers, broadcastings, televisions and public lectures etc. Although the outbreak could be kept under control fairly successfully, the results of *Aedes* surveys reveal that the achievement in source reduction of *Aedes* breeding has so far been unsatisfactory. *Aedes* larval density per 100 houses showed only very gradual lowering each year from 3,010 in 1987 to 1,900, 1,015, 1,373, 604, 570 and 218. Since *Ae. aegypti* is considered playing an important role in the present outbreak, in 1991 and 1992 residual spray of alphacypermethrin was applied to the interior walls of houses in the area with Breteau index of above 35 for *Ae. aegypti*. Undoubtedly it contributed much in suppressing the outbreak in recent years.

INTRODUCTION

Ten species of the subgenus *Stegomyia* in the genus *Aedes* have been recorded to occur in Taiwan (Lien, 1962, 1978), and two of them, i. e. *Aedes albopictus* and *Aedes aegypti*, are closely associated with men, and are considered to be involved in the transmission of dengue (Chan et al., 1971; Lien, 1988, 1989). The susceptibility of these two to dengue viruses has been well documented (Koidzumi et al., 1917; Simmons et al., 1930, 1931; Snjiders et al., 1931; Rosen et al., 1985). In fact during the recent dengue outbreak, 9 pools of dengue serotype one virus were isolated among 189 tested pools consisting of 2,125 female *Ae. aegypti* collected in houses (Lien et al., 1992). *Ae. aegypti* is, therefore, considered more important than *Ae. albopictus*. The latter is very widely distributed from hilly areas of 1,000 meters in elevation down to coastal areas throughout Taiwan, while *Ae. aegypti* is limited to southwestern plain and coastal regions south to tropic of Cancer (Lien, 1962, 1978, 1988, 1989). The distribution of *Ae. aegypti* was by 1964 limited to the Penghu Islands, a small focus in the city of Tainan and the city area of Kaohsiung, owing to the

fact that these areas were excluded from residual spray of DDT for malaria eradication campaign (Anonymous, 1991b).

Before 1945 several dengue outbreaks occurred in Taiwan (Anonymous, 1988, 1989, 1991a, 1991b; Gubler, 1988, 1991; Wu, 1986). Dengue outbreaks were not detected and reported during the period from 1945 to 1980 in Taiwan. In 1981 a dengue outbreak due to serotype two virus was detected for the first time since 1945 on the offshore island Liuchiu (Wu, 1986; Lin et al., 1986). About 80% of the population on the island was affected (Wu, 1986; Anonymous, 1992).

In view of possible dengue outbreak due to the rapid development of national tourism to Southeast Asia, the long-neglected *Aedes* surveillance was resumed since July 1987. After the dengue outbreak was detected in November 1987, the surveillance was greatly intensified, and house mosquitoes were collected for virus isolation (Lien et al., 1992).

Source reduction is the most basic measure for successful control of dengue infection. According to the responsiblities defined by the Dengue Control Center, the Environmental Protection Administration is responsible for source reduction and public relations (Anonymous, 1989, 1991a, 1991b). Health education of the public was soon enforced by propaganda through newspapers, broadcastings, televisions and public lectures etc. by the health and environmental protection authorities.

Materials and Methods

Aedes surveillance: In July 1987 *Aedes* surveillance was resumed from Liuchiu Is., the most receptive area, just shortly before a dengue outbreak was detected on southern Taiwan in November the same year (Lien, 1988). The townships in which *Ae. aegypti* was previously known to occur were given priority for inspection. Indoor and outdoor container habitats were examined from house to house at least for 50 houses in each administrative unit of village. The containers holding water were examined throughly and the mosquito larvae encountered were all removed and preserved in MacGregor's solution for subsequent diagnosis (Anonymous, 1988, 1989, 1991a). About 25 villages were inspected every month, and the results of surveys were analyzed according to the density figures of WHO for house, container and Breteau indices (Brown, 1973; Service, 1976). At the beginning of the surveillance, two teams each consisting of 4 members from the institute carried out the surveillance, and later more than 120 local health workers also participated in the surveillance after they received an intensive training for 3 weeks on mosquito ecology, collecting, specimen mounting, identification and relation of mosquitoes to diseases. A monthly summary of the results of surveys carried out in the previous month was sent to relative health units for remedial action.

Vector Control: As an emergency measure, ultra low volume (ULV) spray of 3.6% water-base permethrin was applied to the interior space of all houses within a 50-meter radius of the house in which a case was found (Anonymous, 1988, 1989, 1991a, 1991b).

Another follow-up spray was done after 7-10 days in order to eliminate newly infected mosquitoes. Since the results of laboratory bioassays revealed that alphacypermethrin 1.5% suspension concentrate when applied to the materials such as plastic-coated plywood, plywood and brown wrapping paper at 50, 30 and 20 mg a. i. per square meter of surface area killed 84-100% female *Ae. aegypti* with 30 minute exposure, even after more than 360 days of spray (Lien et al., 1992). It was decided by the center that the houses in the high risk areas with Breteau index above 35 must be sprayed with the insecticide, in order to bring down the incidence of *Aedes* breeding to a safe level. Residual spray of alphacypermethrin was applied to the interior walls of houses and the undersurface of furniture at 20 mg a. i. per square meter of surface area in southern Taiwan in June-Nov. 1990 and the following two years 1991 and 1992.

RESULTS

The results of *Aedes* surveys carried out between July 1987 and June 1993 were tabulated in Table 1. It revealed that *Aedes* larval density per 100 houses fell rather rapidly from 3,010 in 1987 to 1,900 in 1988, and then remained at the level of 1,000 for the years 1989 and 1990. In 1991, 1992 and 1993 the density decreased rather abruptly to 604, 570 and 219. The ratio of *Ae. aegypti* larvae collected decreased gradually from 65% to 63%, 34%, 25% 8% and 15% during the years 1987 to 1993. Table 2 shows yearly changes of breeding incidence in terms of Breteau index. The percentage of the villages which showed Breteau index above 35 (=above density figure 5) fell from 41% and 46.4% in 1987 and 1988 to 29% and 23.2% in 1989 and 1990, and then to 9%, 9.5% and 1% in 1991, 1992 and 1993 respectively.

Emergency indoor space ULV spray was performed twice at an interval of 7-10 days with 3.6% permethrin emulsion in the houses within a radius of 50 m of the reported case's house as center in each focus since 1987. The operations carried out in the years 1991 and 1992 are tabulated in Table 3. The numbers of houses sprayed were 36,977 (85.6%) and 14,

Table 1. Monthly *Aedes* surveys carried out in Taiwan from July 1987 to 30 June 1993

Year	No. Surveyed			No. of Larvae Collected			*Density
	Vil.	House	Cont.	*Ae. aeg.*	*Ae. alb.*	Total	
1987	41	2,314	2,980	45,505(65%)	24,155	69,660	3,010
1988	179	10,273	16,430	122,401(63%)	72,887	195,288	1,900
1989	324	17,138	30,280	59,844(34%)	114,057	173,901	1,015
1990	271	14,033	19,858	44,377(23%)	148,353	192,730	1,373
1991	435	23,017	28,114	34,809(25%)	104,318	139,127	604
1992	687	36,184	42,580	17,248(8%)	189,029	205,277	570
1993	393	20,475	20,123	6,846(15%)	37,946	44,792	219

* Average number of *Aedes* larvae collected per 100 houses

Table 2. Numbers and percentages of villages with respective density figure for Breteau index

Year	*No. of Tow.	Vil.	No. & % of Villages for Breteau Index 0	1	2	3	4	5	6	7	8	>5
1987	21	41	0	1	2	9	12	7	7	2	1	17
			0.0	2.4	4.9	22.0	29.3	17.0	17.0	4.9	2.4	41.0
1988	46	179	1	8	21	29	37	25	42	13	3	83
			0.6	4.5	11.7	16.2	20.7	14.0	23.5	7.3	1.7	46.4
1989	118	324	3	16	35	71	105	49	35	9	1	94
			1.0	4.9	10.8	21.9	32.4	15.1	10.8	2.8	0.3	29.0
1990	116	271	4	30	50	68	56	33	25	4	1	63
			1.0	11.1	18.5	25.1	20.7	12.2	9.2	1.5	0.4	23.2
1991	149	435	26	79	89	123	79	23	13	3	0	39
			6.0	18.2	20.5	28.3	18.2	5.3	3.0	0.7	0.0	9.0
1992	254	695	50	112	154	196	118	43	14	7	1	65
			7.2	16.1	22.2	28.2	17.0	6.2	2.0	1.0	0.1	9.4
1993	196	398	7	120	108	81	28	3	1	0	0	4
			14.3	30.2	27.1	20.4	7.0	0.8	0.3	0.0	0.0	1.0

* No. of townships & villages surveyed.

Table 3. Emergency indoor space ULV spray with 3.6% permethrin emulsion

Categories	Taipei city	Kaohsiung city	Taiwan prov.	Total
Year 1991				
Target houses	1,016	21,722	20,445	43,183
Houses with total coverage	54	14,826	13,072	27,952
Houses with partial coverage	943	2,723	5,359	9,025
Houses with occupant absent	4	3,159	1,599	4,762
Houses with spray refusal	15	1,014	415	1,444
Houses missed from spraying	1.9%	19.2%	9.9%	14.4%
Year 1992				
Target houses	429	–	14,760	15,189
Houses with total coverage	29	–	11,157	11,186
Houses with partial coverage	394	–	2,532	2,926
Houses with occupant absent	0	–	983	983
Houses with spray refusal	6	–	88	94
Houses missed from spraying	1.4%	–	7.3%	7.1%

112 (92.9%) respectively in 1991 and 1992.

Indoor residual spray of alphacypermethrin (1.5% S. C.) were applied to the interior walls of houses within 2 m above floor in houses in the villages with Breteau index above 35 since June 1990. The operations carried out in the years 1990-1992 were tabulated in Table 4. The numbers of houses sprayed were 5,091 (85.5%), 35,904 (78.5%) and 44,376 (72.1%) respectively in 1990, 1991 and 1992.

From the results of residual spray of alphacypermethrin to the interior walls of houses in the high risk areas with Breteau index above 35, it is apparent that both the larval density and the percentage of the villages with Breteau index above 35 decreased abruptly after 1990. The Figure 1 shows this trend in conjunction with the numbers of reported and confirmed cases.

Table 4. Indoor residual spray of alphacypermethrin (1.5% suspension concentrate) as a rate of 20 mg per square meter of surface area

Categories	Miaoli, Chiai & Tainan	Kaohsiung hsien	Pingtung hsien	Kaohsiung city	Total
Year 1990					
Target houses	2,102	459	1,342	2,333	6,236
Total coverage	1,844	431	1,211	1,249	4,735
Partial coverage	151	11	29	165	356
Occupant absent	40	8	90	644	782
Spray refusal	67	9	12	275	363
Houses not sprayed	5.1%	3.7%	7.6%	39.4%	18.4%
Year 1991					
Target houses	–	3,112	6,034	36,565	45,711
Total coverage	–	1,826	5,096	25,357	32,279
Partial coverage	–	671	473	2,481	3,625
Occupant absent	–	338	245	6,635	7,218
Spray refusal	–	277	220	2,092	2,589
Houses not sprayed	–	19.8%	7.7%	23.9%	21.5%
Year 1992					
Target houses	823	2,327	1,098	57,278	61,526
Total coverage	612	1,261	1,001	30,888	33,762
Partial coverage	129	356	60	10,069	10,614
Occupant absent	64	504	23	11,197	11,788
Spray refusal	18	206	14	5,124	5,362
Houses not sprayed	10%	30.5%	3.4%	28.5%	27.9%

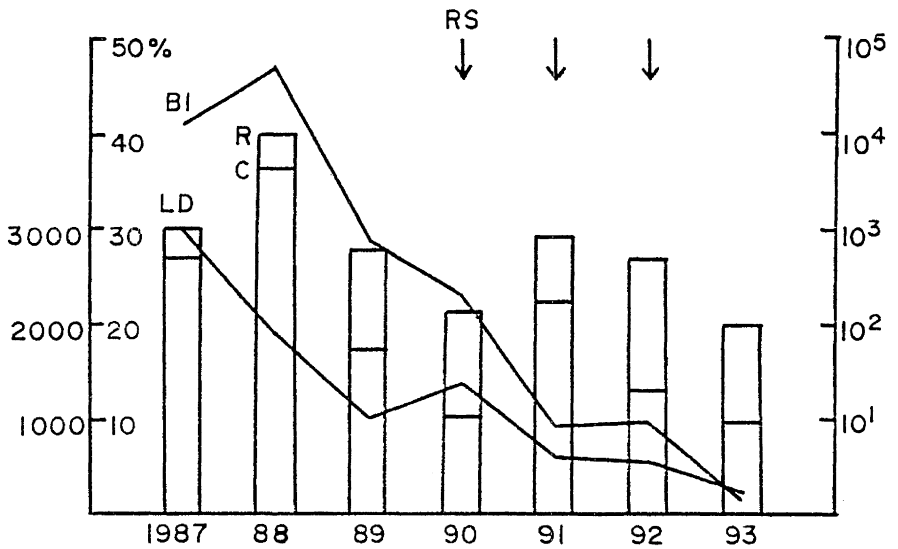

Fig. 1. Effect of residual spray on Breteau index, larval density, reported and confirmed cases

Discussion

In Taiwan as well as elsewhere it is very difficult to persuade people to do source reduction regularly for prolonged period of time. One may do source reduction for fun upon knowing where to look at the beginning, but one may soon forget about that. Health education certainly produced fruits, but not in the active participation of removing aedine breeding habitats, but in the passive way of destroying adults mosquitoes that may invade houses. Many inhabitants in Taiwan upon knowing of dengue transmission by mosquitoes, automatically purchased aerosol insecticide spray cans, mosquito coils, electrocutor traps etc. to combat with house-invading mosquitoes, and it was roughly estimated that during the first 2 years of dengue outbreak more than 2 million sets of electrocutor traps were sold. Prevalence of electrocutor traps in use was investigated in 1,275 houses in four townships of Sanmin of Kaohsiung city, Fengshan city, Tungkang town and Liuchiu Is. during the months of June, July and August 1989, and it was found that an average of 25.2% of the houses inspected was using the traps (Lien 1990). Application of these mosquito killing devices by people certainly contributed much to shortening the life span of vector mosquitoes in houses, and thus suppressing the dengue outbreak (Lien 1990). Nevertheless some people refuse emergency space spray of permethrin in the interior of houses even if somebody in the neighborhood is sick with dengue. On the other hand, they demand local EPA workers to spray insecticide into sewers to kill *Culex* mosquito larvae that have nothing to do with dengue outbreak. A network of community participation in

source reduction of *Aedes* breeding at regular intervals for prolonged period of time must be organized as soon as possible, otherwise dengue outbreaks are inevitable. At present community participation is fragmentary and thus execution of source reduction is still unsatisfactory, therefore the only available preventive measure is to apply residual insecticide to the inner walls of the houses in high risk areas. As a consequence the vector mosquitoes may become resistant to the insecticides in use, therefore we must be alert to possible development of insecticide resistance by the mosquitoes in the future. To eliminate this worriment, it is strongly urged that a network of community participation must be quickly organized through various public associations etc., so that reliance on use of insecticides can be suspended.

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REFERENCES

1) Anonymous (1988): Manual for dengue fever control operation in Taiwan province. Taiwan Provincial Institute of Infectious Diseases, 1−62. (in Chinese)

2) Anonymous (1989): Manual for dengue fever control operation. The Dengue Fever Control Center, The Department of Health & The Environmental Protection Administration, The Executive Yuan, Republic of China, 1−191. (in Chinese)

3) Anonymous (1991): Manual for dengue fever control operation. The Dengue Fever Control Center, The Department of Health & The Environmental Protection Administration, The Executive Yuan, Republic of China, 1−199. (in Chinese)

4) Brown, A. W. A. (1973): Surveillance system for *Aedes aegypti* and related *Stegomyia* mosquitos in terms of density. WHO/VBC/73. 463, 1−32.

5) Chan, Y. C., Ho, B. C. & Chan, K. L. (1971): *Aedes aegypti* and *Aedes albopictus* in Singapore City. Bull. Wld. Hlth. Org., 44, 651−658.

6) Gubler, D. J. (1988): Surveillance, prevention and control of epidemic dengue in Taiwan, Republic of China (ROC). Assignment Report 10−15 Sept. 1988, 1−9.

7) Gubler, D. J. (1991): Surveillance, prevention and control epidemic dengue in Taiwan, Republic of China. Assignment Report 20−26 Oct. 1991, 1−14.

8) Koidzumi, M., Yamaguchi, K. & Tonomura, K. (1917): Study of dengue. J. Formosan Med. Assoc., No. 176, 369−395; No. 177, 432−463.

9) Lien, J. C. (1962): Non-anopheline mosquitoes of Taiwan: Annotated catalog and bibliography. Pacific Insects, 4, 615−649.

10) Lien, J. C. (1978): The ecology of the mosquitoes in Taiwan province and their control. Manuscripts for the Seminar on "Ecology and Control of Insects" held by the Academia Sinica, 15−16 May, 37−69. (in Chinese)

11) Lien, J. C. (1988): Entomological aspects of dengue fever. Kaohsiung Medical College Tropical Medicine Research Center Symposium on Dengue, Abstracts, Kaohsiung, April 15, 1988, 9−11. (in Chinese and English)

12) Lien, J. C. (1989): Entomological surveillance on the vectors of dengue fever in Taiwan. Program and Abstracts of Panel Lecture and Workshop on Arbovirus, Taipei, 20−22 Feb. 1989: 14; Symposium on Dengue Fever Program and Abstracts, Taipei, 25−26 Feb. 1989, 8.

13) Lien, J. C. (1990): Observation and impressions on the dengue fever outbreak and control in Taiwan. Health Monthly 4 (4), 17−19. (in Chinese)

14) Lien, J. C., Wu, Y. C., Huang, H. M., Chung, C. L., Yueh, I. Y. & Lu, L. C. (1992): Survey and control of dengue fever vectors, *Aedes aegypti* and *Ae. albopictus*, in Taiwan during 1987−1992. A Worldwide Problem, A Common Strategy. Proceedings of the International Conference on Dengue and *Aedes aegypti* Community-based Control Mexico DF November, 1992, 185−195.

15) Rosen, L., Roseboom, L. E., Gubler, D. J., Lien, J. C. & Chaniotis, B. N. (1985): Comparative susceptibility of mosquito species to oral and parenteral infection with dengue and Japanese encephalitis viruses. Am. J. Trop. Med. Hyg., 34, 603−615.

16) Service, M. W. (1976): Mosquito ecology. Field sampling methods. London, 1−584.

17) Simmons, J. S., John, J. H. St. & Reynolds, F. H. K. (1930): Transmission of dengue fever by Aedes albopictus Skuse. Philippine J. Sci., 41, 215−231.

18) Simmons, J. S., John, J. H. St. & Reynolds, F. H. K. (1931): Experimental studies of dengue. Bureau of Science, Manila. Monograph 29, 1−489.

19) Snijders, E. P., Dinger, E. & Schuffner, W. A. P. (1931): On the transmission of dengue in Sumatra. Am. J. Trop. Med., 11, 171−189.