Analysis on Dengue Vector Density Survey in Kaohsiung and Pingtung Areas of Southern Taiwan, 2004-2008

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Abstract

This study collected the dengue mosquito survey data obtained in 1346 villages of 71 townships/districts/cities in Kaohsiung and Pingtung areas during 2004-2008 and performed the analysis of correlation between the weekly occurred dengue cases and various vector indexes, as well as other analysis relevant to mosquito breeding source.

Based on the surveys conducted during the last five years, the *A. aegypti* was not found only in Maulin Township in Kaohsiung City and County and in 15% of townships/cities in Pingtung County but *A. albopictus* was found in all villages in Kaohsiung and Pingtung areas. Although the geographical distribution of *A. albopictus* was wider than that of *A. aegypti* in Kaohsiung and Pingtung areas, the distribution of *A. aegypti* in densely populated Kaohsiung City was wider than that of *A. albopictus*. Moreover, the number of villages where only *A. aegypti* was

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found in Kaohsiung City appeared to be an increasing trend, which was not found in Kaohsiung and Pingtung Counties. The item of others, such as drainage ditch, water tower, and canvas for shelter use, unclassified type of breeding source, represented the largest part of mosquito breeding source, and, then, in the descending order, water bucket, follower vase, plant saucer, pottery pot, discarded tire, polystyrene box and plate, plastic basket, empty can, cup, refrigerator saucer, and flooded basement. The fact that the unclassified mosquito breeding source reached as high as 33% suggests the necessity of redefining the classification for the type of breeding source. A correlation between Adult *A. aegypti* Index and annual dengue incidence was identified in all villages of Kaohsiung and Pingtung areas in the recent five years, and their correlation coefficients were higher than those between Adult *A. albopictus* Index and dengue incidence. In addition, a correlation was also identified between the weekly occurred dengue cases and Adult *A. aegypti* Index, but no correlation was found between dengue cases and Adult *A. albopictus* Index. Analysis of the performance among governments of Kaohsiung and Pingtung County (City) on density survey revealed that Kaohsiung City has completed the largest number of villages, 42,497; Pingtung County has completed the highest number of households, 3,067,830; Pingtung County has identified the largest number of water-holding containers, 2,835,610; and Pingtung County has removed the largest number of breeding containers, 162,828. In addition, the highest ratio, 4:6, of water-holding containers found indoor versus outdoor occurred in Kaohsiung City, and the ratio of breeding containers found indoor versus outdoor fell between 1:9 and 2:8 in Kaohsiung and Pingtung areas.

Keywords: dengue fever, *Aedes aegypti*, *Aedes albopictus*, mosquito breeding source, geographical mosquito distribution

Introduction

Dengue and dengue hemorrhagic fever are reemerging diseases, mainly occurring in tropical regions located between latitude 25°N and 25°S. Dengue fever is one of an infectious viral diseases transmitted primarily through the bite of *Aedes aegypti*. Other species of mosquitoes, such as *A. albopictus*, *A. polynesiensis*, and *A. rotumae*, also can play the vectors of dengue fever, but they are less efficient than *A. aegypti* [1]. Dengue fever is caused by dengue virus that belongs to the subgenus dengue virus group of the genus *Flavivirus* of the *Flaviviridae* family. The subgenus dengue virus group includes four serologically different dengue viruses, named as type I, type II, type III, and type IV virus, respectively, according to their antigenicity. In patients of dengue hemorrhagic fever and dengue shock syndrome, which are caused by cross-infected with different types of virus [2], the fatality rate reaches up to 30% if they do not receive appropriate treatments [3].

Although some diseases caused by virus in genus *Flavivirus*, such as Japanese encephalitis, can be prevented by vaccine injection, no efficient vaccine has been developed for dengue fever currently. The only available way to prevent the spread of dengue fever is to eliminate breeding of *A. aegypti*. In this respect, some examples can be a reference in conducting the elimination of mosquito breeding source, such as yellow fever and *A. aegypti* eradication program initiated by Pan-America Health Organization during 1946-1970 [4], breeding source elimination plan implemented in a heavily militarized way in Cuba in1981 [5], and a 35 years of experience

in vector elimination program for dengue control in Singapore [6]. However, dengue fever has become an endemic disease in some of the Southeast Asia Countries, such as Thailand, Indonesia, Vietnam, Malaysia, Philippines, and Singapore, and in several Middle and South America countries since the late 1980's. The number of dengue fever cases reported by these Southeast Asia Countries in 2008 ranged from 6,567 to 101,646. In the same year, there are 488 confirmed indigenous dengue cases in Taiwan. There has been no large-scale dengue epidemic in Kaohsiung and Pingtung Areas of Southern Taiwan since it happened in 2002. This success should be credited to the accumulated experience in disease control and full efforts made by colleague in relevant authorities [7], particularly those in Health Bureau of Kaohsiung City, Kaohsiung County, and Pingtung County. They actively implement the vector density survey every year. In this study, we collected and analyzed the survey data obtained in the last five years. Our purposes were to explore the distribution of *A. aegypti* and its major breeding sources, the association between the occurrence of dengue cases and the vector density, and the performance of vector density survey among these counties. The results of analysis would be part of the reference in performing the dengue control.

Materials and Methods

Vector Density Survey

In residential areas, 50-100 households were randomly sampled from each village in each investigation. In the village where total number of households is less than 50, all of them would be sampled for investigation. In remote areas where households are sparsely located, a 3-4 hour

investigation would be conducted by three investigators for the village. The density of vector was expressed by using the Breteau index for larvae and Adult index for adult mosquito.

In addition to residential sites, places where people gather or mosquito infest or breed, such as institutions, schools, undeveloped spaces, parks, vegetable planting fields, and mountain areas, were also included in the list to be investigated. For all these places, the investigation would cover all the corners where are accessible to investigators (three investigators for 3-4 hours), and the Container index would be used to represent the density of larvae.

The 2004-2006 edition of Dengue Control Guideline recommended every county to conduct monthly vector density survey by randomly sample at least 15% of villages in residential areas for. The 2007-2008 edition of the guideline specifically recommended Tainan County, Tainan City, Kaohsiung County, Kaohsiung City and Pingtung County randomly investigate at least 50% of their villages. Other counties were recommended to investigate at least 15% of their villages during June through November, and at least 10% during December through next May.

Vector Density Index and Their Calculations

Breteau index represents the number of containers found with *Aedes* larvae in 100 households investigated. Container index means the percentage of containers found with *Aedes* larvae in 100 containers investigated. Adult index was used to express the density of adult *A. aegypti* (or *A. albopictus*) mosquito, which means the average number of female adult *A. aegypti* (or *A. albopictus*) mosquito caught in the households. Household index indicated the percentage of households found with *Aedes* larvae in 100 households

investigated. The mean annual Breteau index was calculated by dividing the total number of containers found with larvae by the total number of households investigated in the year, and then multiply by 100. Similar procedures were performed for calculations of other indexes.

Coverage of Villages Investigated and Study Limitations

Totally, a number of 111,746 investigations have been conducted for 1364 villages in 71 districts or townships of Kaohsiung and Pingtung areas in the last five years, including those conducted in 459 villages from 11 districts of Kaohsiung City, 441 villages from 27 townships of Kaohsiung County, and 464 villages from 33 townships of Pingtung County. Among these investigations, 644 were not included in the analysis because of insufficient information on villages. The overall coverage of investigation has reached up to 100% of villages in Kaohsiung and Pingtung areas in the last five years. Our study had some limitations, most were relevant of accuracy of vector density survey. Our survey was not “carpet combing”, but investigated households sampled randomly. However, vacant households or residents who denied our survey would make our investigation susceptible to selection bias. Besides, although all our staff received the standard training programs before initiation of survey, not all of them had the same skills or experiences in finding hidden breeding sources, such as roof gutters, ditch, and flooded basement, etc.

Analysis of Association between Population Density of Townships and Incidence Rate of Dengue Fever in Kaohsiung and Pingtung Areas during 2004-2008

We first obtained the data of population density (residents/per square kilometer) of the 71 townships in each of the last five years according to the reports

of December 2008 on Website http://sowf.moi.gov.tw/stat/month/m1-07.xls and calculated annual incidence rate of dengue fever for each of the townships. Then, we applied the NCSS statistical software to analyze the correlation between population density and dengue incidence.

Analysis of *A. aegypti* Distribution of Each Township and Village in Kaohsiung and Pingtung Areas during 2004-2008

We first calculated the percentage of *A. aegypti* (including male and female) caught in each of the 71 townships versus total number of *Aedes* mosquito (including male and female) caught in Kaohsiung and Pingtung areas during five years. Next, we applied the same procedures to calculate the percentage for each of the 1,364 villages. Finally, the distributions of the percentages were plotted on the map by using the ArcGIS software.

Categorization and Analysis of Townships (Villages) Based on the Investigation of *A. aegypti* or *A. albopictus* in Kaohsiung and Pingtung Areas during 2004-2008

All the townships (or villages) investigated were divided into two categories: one is the townships (villages) where *A. aegypti* or *A. albopictus* once found at least in one single year of investigation, the other is the townships (villages) where *A. aegypti* or *A. albopictus* has been found every year.

Categorization and Percentage Calculations of Villages Based on the Investigation of Adult *A. aegypti* and *A. albopictus* in Kaohsiung and Pingtung Areas during 2004-2008

All the villages investigated were classified as one of the five categories according to the results of adult *A. aegypti* and *A. albopictus* found in each of the five years: no *Aedes* mosquito was found in the year, only *A. albopictus* was found, only *A. aegypti* was found, both *A. aegypti* and *A.*

albopictus were found, and no investigation was conducted. Then, the percentages of villages were calculated for each of the categories. Finally, the method of linear regression analysis was performed to look at whether the number of villages where only *A. aegypti* was found increased yearly.

Analysis of Association between Dengue Incidence and Various Vector Indexes in Villages in Kaohsiung and Pingtung Areas during 2004-2008

The number of mid-year population (denominator) provided by the Department of Household Registration, Ministry of the Interior in each township and village, and the accumulated number of dengue cases yearly occurred in each village (numerator) were used to calculate the dengue incidence for each village. A five-year vector index was calculated for each village by using the Excel software. Then, the analysis of association between dengue incidence and vector index was conducted.

Analysis of Association between Weekly Vector indexes and Weekly Occurred Dengue Cases in Kaohsiung and Pingtung Areas during 2004-2008

Weekly accumulated number of dengue cases and weekly various vector indexes were calculated and, then, the analysis of association between two of them were conducted.

Categorization and Statistics of Mosquito Breeding Sources

Breeding sources found and recorded during the almost five years of investigation were classified as holding with water, infested with *Aedes* larvae, and indoor or outdoor locations based on the characters of the sources, and separated into twelve types, including vase, plant saucer, refrigerator saucer, plastic basket, pottery pot, water bucket, polystyrene box and plate, empty can, cup, flooded basement, discarded tire, and

others. The number of the breeding sources was calculated for each of the characters and types. However, the calculations did not include the number of breeding source found in May 2004 because of lack of the information on their characters and types.

Analysis of the Vector Survey Performance of Kaohsiung and Pingtung

To analyze the vector survey performance of Kaohsiung City, Kaohsiung County, and Pingtung County, the number of investigations conducted in villages, average number of households investigated in each investigation, average number of water-holding containers and breeding containers in each investigation, and total number of water-holding containers and breeding containers found indoor and outdoor were calculated by year and location.

Results

Analysis of Association between Population Density of Townships and Incidence Rate of Dengue Fever in Kaohsiung and Pingtung Areas during 2004-2008

A correlation (r=0.369, *p*-value<0.001) between average population density and dengue incidence was found. This represents that population density can affect the occurrence and spread of dengue cases.

Analysis of *A. aegypti* Distribution of Each Township and Village in Kaohsiung and Pingtung Areas during 2004-2008

The overall percentage of *A. aegypti* for each township in the last five years is shown in Figure 1. From this analysis, we found that the percentage of *A. aegypti* accounts for more than 90% of total number of *Aedes* mosquito in some township such as Districts of Cianjhen, Cijin, Cianjin,

Sinsing, Sanmin, Lingya, and Yancheng in Kaohsiung City, and no *A. aegypti* was caught in Maulin Township of Kaohsiung County and Jhutian, Linbian, Kanding, Sinbi, Manjhou Township of Pingtung County. The overall percentage of *A. aegypti* for each village in the last five years is shown in Figure 2.

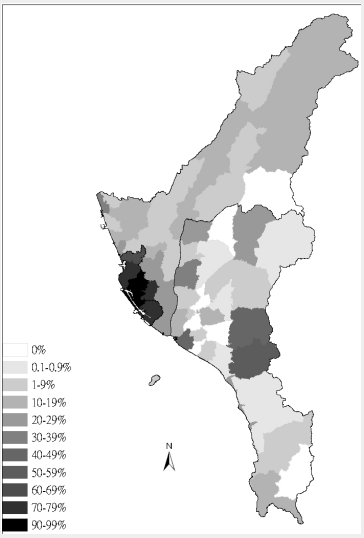

Figure 1. Proportion of *A. aegypti* and *A. albopicus* collected in townships of Kaohsiung and Pingtung areas

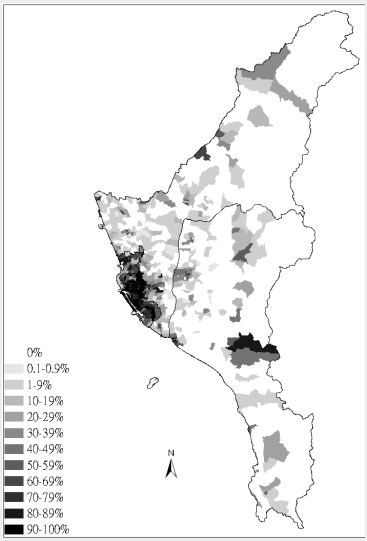

Figure 2. Proportion of *A. aegypti* and *A. albopicus* collected in villages of Kaohsiung and Pingtung areas

Categorization and Analysis of Townships (Villages) Based on the Investigation of *A. aegypti* or *A. albopictus* in Kaohsiung and Pingtung Areas during 2004-2008

A total of 947 villages of 65 townships once found *A. aegypti* (at least in one single year) during the last five years. Specifically, all of the 459 villages of 11 districts in Kaohsiung City once found *A. aegypti;* except Maulin Township, other 26 townships covered 306 villages in Kaohsiung

County once found *A. aegypti;* except Jhutian, Linbian, Kanding, Sinbi, Manjhou Township, other 28 townships covered 182 villages in Pingtung County once found *A. aegypti*. It should be noted that *A. aegypti* was discovered in mountain areas, Namajia and Taoyuan Townships of Kaohsiung County. This represents that the distribution of *A. aegypti* has reached attitude as high as 1500 meter. Other mountain areas in Pingtung County, such as Sandimen, Wutai, Majia, Taiwu, Laiyi, Chunri, Shizi, and Mudan Township, also once found *A. aegypti*. In addition, *A. albopictus* was once found in a total of 1291 villages of 71 townships, including all villages in Kaohsiung and Pingtung County, during the last five years. (Table 1) The places where *A. aegypti* has been found every year was 563 villages of 26 townships/districts in Kaohsiung and Pingtung areas, including 404 villages of 11 districts in Kaohsiung City, 90 villages of 9 townships/cities such as Fengshan City and Niaosong, Daliao, Renwu, Jiaxian, Linyuan, Alian, Ziguan, Hunei Townships in Kaohsiung County, and 69 villages of 6 townships/cities such as Pingdong City, Chaozhou, Donggang, Ligang, Chunri, and Sandimen townships in Pingtung County. Except for *A. aegypti*, *A. albopictus* has also been found every year in 571 villages of 64 townships/districts/cities, including 50 villages of 7 districts in Kaohsiung City, 196 villages of 26 townships/cities in Kaohsiung County, and 325 villages of 31 townships/cities in Pingtung County. (Table2) This study shows that the geographical distribution of *A. aegypti* was wider than *A. albopictus* in Kaohsiung City, but a reverse situation was found in Kaohsiung and Pingtung Counties.

Table 1. Number of townships/districts/cities (villages) ever with Aedes mosquito at least in one single year of investigation*

County/city	Townships/districts/cities		Villages	
	A. aegypti (%)	*A. albopictus* (%)	*A. aegypti* (%)	*A. albopictus* (%)
KS City	11/11(100)	11/11(100)	459/459(100)	386/459(84)
KS County	26/27(96)	27/27(100)	306/441(69)	441/441(100)
PT County	28/33(85)	33/33(100)	182/464(39)	464/464(100)
Total	65/71(92)	71/71(100)	947/1364(69)	1291/1364(95)

* Denominator is the total number of townships/districts/cities or villages. Numerator is the number of townships/districts/cities or villages with *Aedes* mosquito.

Table 2. Number of townships/districts/cities (villages) with Aedes mosquito in every year of investigation*

County/city	Townships/districts/cities		Villages	
	A. aegypti (%)	*A. albopictus* (%)	*A. aegypti* (%)	*A. albopictus* (%)
KS City	11/11(100)	7/11(64)	404/459(88)	50/459(11)
KS County	9/27(33)	26/27(96)	90/441(20)	196/441(44)
PT County	6/33(18)	31/33(94)	69/464(15)	325/464(70)
Total	26/71(37)	64/71(90)	563/1364(41)	571/1364(42)

* Denominator is the total number of townships/districts/cities or villages. Numerator is the number of townships/districts/cities or villages with *Aedes* mosquito.

Categorization and Percentage Calculations of Villages Based on the Investigation of Adult *A. aegypti* and *A. albopictus* in Kaohsiung and Pingtung Areas during 2004-2008

As shown in Figure 3-1, the number of villages in Kaohsiung City where only *A. aegypti* was found was only 224 in 2004, and then 172, 255, 216, and 304 in 2005, 2006, 2007 and 2008, respectively. The linear regression analysis suggests an increased trend (p-value<0.05) on the number of villages with only *A. aegypti* being found. Figure 3-2 shows the results of investigation in Kaohsiung County. The number of villages where only *A. aegypti* was found was 14 in 2004, and then 14, 18, 2, and 9 in 2005, 2006, 2007 and 2008, respectively. No increased trend (p-value>0.05) was

found. Figure 3-3 provides the results of investigation in Pingtung County. The number of villages where only *A. aegypti* was found was 10 in 2004, and then 4, 1, 6, and 4 in 2005, 2006, 2007 and 2008, respectively. No increased trend (p-value>0.05) was found.

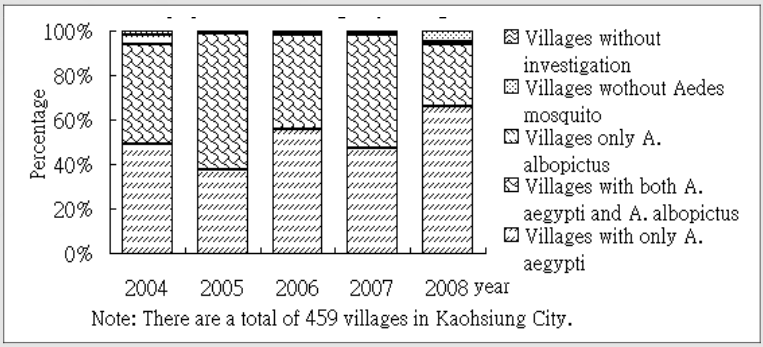

Figure 3-1. Percentage of villages based on the investigation of *Aedes* mpsquito in Kaohsiung City during 2004-2008

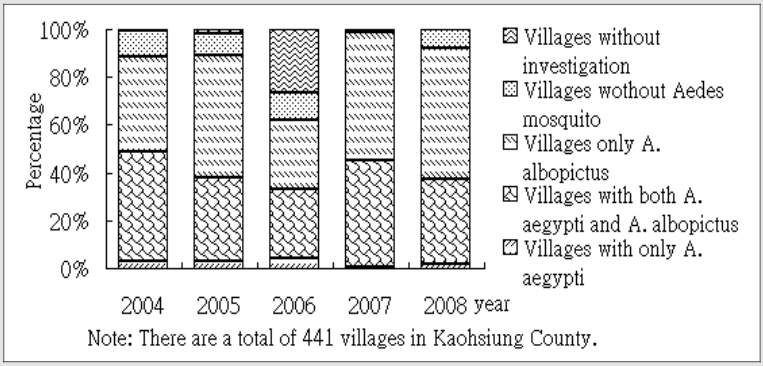

Figure 3-2. Percentage of villages based on the investigation of *Aedes* mpsquito in Kaohsiung County during 2004-2008

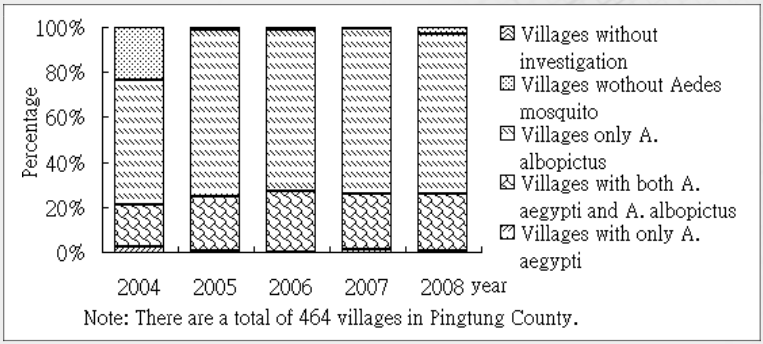

Figure 3-3. Percentage of villages based on the investigation of *Aedes* mpsquito in Pingtung County during 2004-2008

Analysis of Association between Dengue Incidence and Various Vector indexes in Villages in Kaohsiung and Pingtung Areas during 2004-2008

The results show that a correlation existed between dengue incidence and Adult *A. aegypti* Index in each of the five years, meaning that *A. aegypti* plays a key vector in the dengue epidemic. In 2006, the correlation was found between dengue incidence and Adult *A. albopictus* index, representing that both *A. aegypti* and *A. albopictus* were key vectors of dengue epidemic that year. A correlation between dengue incidence and both Breteau index and Household Index was found in 2004 and 2006, but no correlation in other years. For container index, the correlation was found in 2006 and 2008, but not in other years. The latter three indexes are all used for monitor of *Aedes* larvae but they did not separate the larvae were *A. aegypti* or *A. albopictus.* As shown in Figure 2, the percentage of *A. aegypti* was different among villages. Therefore, the larvae index cannot represent the real distribution of adult *A. aegypti*. As a result, the correlation between the three kinds of larvae indexes and dengue incidence is difficult to analyze.

Table 3. Correlation between the dengue incidence and various vector index

Index	correlation coefficient (r)				
	2004	2005	2006	2007	2008
Breteau index	0.133**	0.028	0.076*	0.020	0.034
Container index	0.019	0.006	0.103**	0.032	0.068*
House index	0.122**	0.030	0.071*	0.014	0.024
Adult *A. aegypti* index	0.182**	0.218**	0.290**	0.089*	0.151**
Adult *A. albopictus* index	0.010	0.034	0.144**	0.040	0.044

Note: **p*-value <0.05, ***p*-value <0.001.

Analysis of Correlation between Weekly Vector indexes and Weekly Occurred Dengue Cases in Kaohsiung and Pingtung Areas during 2004-2008

The weekly dengue cases, Breteau index and adult *A. aegypti* index for the last five years is shown in Figure 4. A significant correlation (r=0.611, *p*-value<0.001) was identified between the weekly occurred dengue cases and Adult *A. aegypti* Index obtained five weeks before the disease occurrence, but no correlation was found between dengue cases and Adult *A. albopictus* Index (*p*-value>0.05). Each index showed different levels of correlation. Table 4 is the analysis of correlation coefficient.

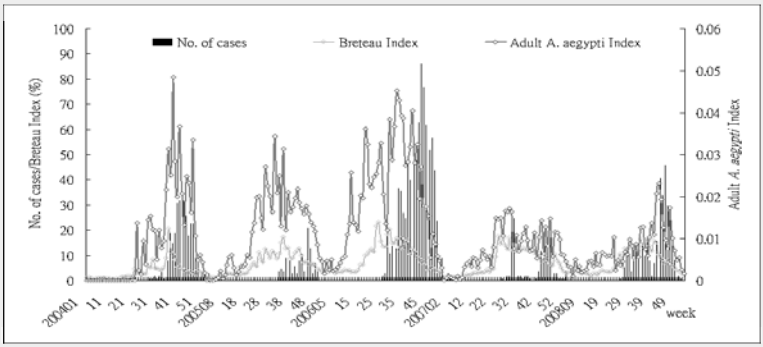

Figure 4. Trend of indigenous dengue cases and vector indexes during 2004-2008
Note: Y axis on right side represents the Adult *A. aegypti* Index; Y axis on left side represents dengue case number and Breteau index.

Table 4. Correlation between weekly vector indexes and weekly accumulated number of dengue cases

Index	correlation coefficient (r)*								
	Same wk	pre-wk 1	pre-wk 2	pre-wk 3	pre-wk 4	pre-wk 5	pre-wk 6	pre-wk 7	pre-wk 8
Breteau index	0.232	0.296	0.350	0.409	0.483	0.534	0.549	0.559	0.567
Container index	0.289	0.357	0.412	0.475	0.536	0.579	0.592	0.600	0.602
House index	0.236	0.297	0.344	0.398	0.468	0.515	0.529	0.543	0.547
Adult A. aegypti index	0.440	0.494	0.544	0.578	0.603	0.611	0.578	0.569	0.583
Adult A. albopictus index	0.033	0.052	0.051	0.064	0.069	0.071	0.070	0.077	0.072

* Correlation coefficient of the 'same week' means the data of both vector index and case number used for analysis happened in the same week, the 'pre-week 5' means the vector index obtained six weeks (a five weeks separation) before the dengue occurred was used, the rest may be deduced by analogy. Except that no correlation was found between dengue cases and Adult *A. albopictus* Index (p-value>0.05), all other Indexes had different extent of correlation, with a p–value less than 0.001, between two of them.

Categorization and Statistics of Mosquito Breeding Sources

The analysis shows the highest percentage of container holding with water was water bucket, 29.4%; and then others, 20.6%; flower vase, 11.8%; plant saucer, 10.7%; refrigerator saucer, 5.7%; cup, 4.8%; pottery pot, 4.5%; empty can, 4.3%; plastic basket, 3.4%; polystyrene box and plate, 2.9%; discarded tire, 1.6%; and flooded basement, 0.2%. The highest percentage of container infested with *Aedes* larvae was the type of others, 32.8%; and then water bucket, 28.2%; flower vase, 6.5%; plant saucer, 5.6%; pottery pot, 5.4%; discarded tire, 5.4%; polystyrene box and plate, 4.5%; plastic basket, 4.3%; empty can, 3.7%; cup, 2.8%; refrigerator saucer, 0.4% and flooded basement, 0.4%. (Figure 5) The fact that approximately 33% of breeding container was type unclassified suggests it is necessary to re-classify the type of breeding sources.

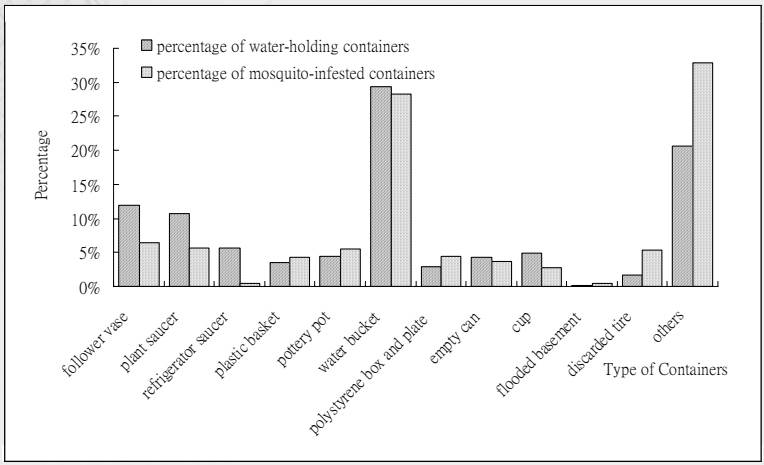

Figure 5. Categorization and statistics of mosquito breeding sources found during 2004-2008

Analysis of the Performance of Kaohsiung and Pingtung County (City) on Vector Survey

1. Number of investigations conducted in villages of Kaohsiung and Pingtung areas during 2004-2008: The Kaohsiung City had the highest number of investigations, next, Kaohsiung County, and then Pingtung County, as shown in Table 5.

Table 5. Number of investigations conducted during 2004-2008 (unit: no. of investigation)

Counties	2004	2005	2006	2007	2008	Total
KS City	19,667	7,658	3,647	7,398	4,127	42,497
KS County	8,387	5,456	3,490	7,777	12,563	37,673
PT County	6,463	9,680	3,853	6,964	13,972	30,932

2. Average number of households completed, and average number of water-holding containers and breeding containers found, in a single investigation during 2004-2008.

(1) Average number of households completed in a single investigation: The Pingtung County had the highest average number of households, next, Kaohsiung City, and then Kaohsiung County, as shown in Table 6.

Table 6. Average number of households completed in a single investigation during 2004-2008 (unit: household)

Counties	2004	2005	2006	2007	2008	5-year average	5-year accumulation
KS City	87.5	56.6	62.8	55.7	62.9	71.9	3,053,975
KS County	55.1	53.4	55.0	54.1	50.9	53.2	2,005,734
PT County	95.9	96.7	121.9	84.8	113.7	99.2	3,067,830

(2) Average number of water-holding containers found in a single investigation: The Pingtung County had the highest average number of water-holding containers, next, Kaohsiung City, and then Kaohsiung County, as shown in Table 7.

Table 7. Average number of water-holding containers found in a single investigation during 2004-2008 (unit: piece)

Counties	2004	2005	2006	2007	2008	5-year average	5-year accumulation
KS City	51.6	51.8	84.4	69.3	79.2	60.2	2,557,926
KS County	35.2	34.2	38.9	33.9	30.9	33.7	1,269,449
PT County	88.6	103.3	114.9	68.9	85.8	91.7	2,835,610

(3) Average number of breeding containers found in a single investigation: The Pingtung County had the highest average number of breeding containers, next, Kaohsiung County, and then Kaohsiung City, as shown in Table 8.

Table 8. Average number of breeding containers found in a single investigation during 2004-2008 (unit: piece)

Counties	2004	2005	2006	2007	2008	5-year average	5-year accumulation
KS City	1.4	2.6	5.5	3.4	4.3	2.6	110,490
KS County	2.5	3.9	3.7	4.9	4.0	3.8	143,783
PT County	4.2	5.0	8.3	4.2	6.7	5.3	162,828

3. Ratio of water-holding containers found indoor versus outdoor: A total of 1,000,132 pieces and 1,557,794 pieces of water-holding containers were identified indoor and outdoor (indoor/outdoor ratio: 39/61), respectively in Kaohsiung City during the last five years, 429,990 pieces and 839,459 pieces (indoor/outdoor ratio: 34/66) in Kaohsiung County, and 889,937 pieces and 1,945,673 pieces (indoor/outdoor ratio: 31/69) in Pingtung County.
4. Ratio of breeding containers found indoor versus outdoor: A total of 22,497 pieces and 87,993 pieces of breeding containers were identified indoor and outdoor (indoor/outdoor ratio: 20/80), respectively in Kaohsiung City during the last five years, 12,167 pieces and 131,616 pieces (indoor/outdoor ratio: 8/92) in Kaohsiung County, and 11,778 pieces and 151,050 pieces (indoor/outdoor ratio: 7/93) in Pingtung County.

Discussions and Suggestions

The significant correlation (r=0.369) identified between residential population density and dengue incidence in villages of Kaohsiung and Pingtung areas in recent five years revealed that the spread of dengue epidemic was partially dependent on population density. Basically, dengue fever is a vector-borne disease spreading through mosquito bite. Previous

studies conducted in the most seriously dengue-affected 25 townships/districts/cities during 1987-1988 demonstrated the significant correlation between the dengue epidemic areas and *A. aegypti* density (r=0.671), but no correlation was found between dengue epidemic and *A. albopictus* (r=0.173) [8]. Therefore, the areas with a higher *A. aegypti* density had a relatively higher dengue incidence. This study shows that, in eleven administrative districts, such as Gushan, Cianjhen, Cijin, Cianjin, Sinsing, Sanmin, Lingya, and Yancheng, Zuoying, Xiaogang districts in Kaohsiung City and Fengshan City in Kaohsiung County, as shown in Figure 1, and 445 villages, including 384 in Kaohsiung City, 49 in Kaohsiung County (37 among 49 in Fengshan City), 12 in Pingtung County (6 among 12 in Pingtung City), as shown in Figure 2, the number of *A. aegypti* accounted for more than 70% of total number of *Aedes* mosquito. We, therefore, recommend that these townships/districts/cities or villages should be considered as high risk areas of dengue epidemic and actively enforce relevant disease control activities.

A survey of dengue mosquito, conducted by Health Bureau of each County and Taiwan Centers for Disease Control during 2003-2004, indicated that all of the townships/districts/cities in Kaohsiung City and County and 64% of those in Pingtung County have identified *A. aegypti* [9]. In this study, we found that all townships/districts/cities in Kaohsiung City and County except Maulin Township and 85% of townships/districts/cities in Pingtung County have discovered *A. aegypti*. In addition, the places where the number of villages only *A. aegypti* was found appeared to be an increasing trend were only in Kaohsiung City, but not in Kaohsiung and Pingtung Counties, which the reasons need to be further

explored.

Table 3 shows that the dengue incidence every year in villages of Kaohsiung and Pingtung areas was associated with only the Adult *A. aegypti* index that, therefore, can be used as one of the indicators to predict dengue epidemic. However, the dengue incidence in 2006 was also associated with Adult *A. albopictus* Index (as shown in Table 3, r=0.144). Since the 952 dengue cases in Kaohsiung and Pingtung areas in 2006 was mainly occurred in Cianjhen, Sanmin, and Lingya Districts of Kaohsiung City with 302, 135, and 157 cases, respectively, and Fengshan City in Kaohsiung County with 164 cases [10], and, as shown in Figure 1, the number of *A. aegypti* accounted for more than 90% of total number of *Aedes* mosquito in Cianjhen, Sanmin, and Lingya Districts, but it was only 69.5% in Fengshan City, we, therefore, speculate that the association in 2006 was related to the dengue situation occurred in Fengshan City. Similarly, analysis of correlation between weekly vector indexes and weekly occurred dengue cases appeared a significant correlation between the number of dengue cases and Adult *A. aegypti* Index, especially, that obtained five weeks before the disease occurrence had the highest correlation coefficient (r=0.611), but this correlation was not found between dengue cases and Adult *A. albopictus* Index. This support that *A. aegypti* was the key vector of dengue fever in Kaohsiung and Pingtung areas although other Indexes such as Breteau index, container index, and Household Index also had different extent of correlation with dengue occurrence. Currently, in order to work efficiently, health workers only survey adult *Aedes* mosquitoes and remove the breeding sources, but does not further differentiate *Aedes* larvae.

Based on this study, water bucket and flower vase was the major mosquito breeding sources, revealing that the residents' habits related to the creation of breeding sources need to be improved through health education. The fact that a considerably high percentage of breeding sources were unclassified appeared that the classification for the type of breeding source in dengue vector survey form needed to be redefined, for example, by increasing the items of frequently found breeding sources, such as drainage ditch, water tower, and canvas for shelter use.

A comparison of the number of investigations completed in villages for vector survey among counties in Kaohsiung and Pingtung areas found that Kaohsiung City shared the largest part of the total number of investigations, but the number of investigations completed in villages was 3,853 and 3,972 in 2006 and 2008, respectively, a relatively lower, as compared with other years. Moreover, the number of households investigated in this City in 2006 and 2008 was 229,077 and 259,555, respectively. Again, it was relatively lower than other years. The lower number of investigation in the two years in Kaohsiung City was probably resulting from the relatively serious dengue epidemic. Since most control activities will focus on emergency insecticide spray and epidemiological investigation when dengue epidemic occurred according to the Guidelines of Dengue Control and Prevention, the number of vector survey was low due to the limited resources. The Pingtung County had completed the highest average number of households, and found the highest average number of water-holding and breeding containers, in a single investigation. However, we still can not make judgments on the level of performance on the breeding source elimination of the three counties/cities merely from these numbers since Pingtung County had less manpower

resources and a lower population density than Kaohsiung County and City. Moreover, these numbers partially depended on resource allocation for the dengue epidemic control and on the participation levels of the environment protection agency. The analysis of indoor/outdoor ratio of water-holding containers, except providing the information on the distribution of water-holding containers, can be used as an indicator to evaluate the performance on the breeding source investigation. A ratio of approximately 1:1 means health workers work diligently indoors and outdoors. Therefore, the finding that the range of ratio was between 3/7 and 4/6 in the last five years in Kaohsiung and Pingtung areas suggested that there is room for improvement in the investigations. As for breeding container survey, the indoor/outdoor ratio can provide the information on the distribution of breeding containers in our environment and be used as a reference criterion in evaluating the performance on whether health workers have carefully inspected the breeding of mosquito in the water-holding containers. The experience accumulated in recent five years among counties in Kaohsiung and Pingtung areas shows that the indoor/outdoor ratio was in the range of 1/9 and 2/8. Therefore, the ratio should be able to be used as an indicator of evaluating the level of investigation experiences and skills.

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