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Original Article

Evaluation of Performance of Space Sprayer for Dengue Vector Control

Wei-Tai Hsia[1], Ho-Sheng Wu[1], Lili-Lee[1], Shiou-Pin Lin[1], Fang-Ying Shen[2]

1. Research and Diagnostic Center, Centers for Disease Control, Taiwan
2. National Taiwan University, Institute of Occupational Medicine and Industrial Hygiene

Abstract

With high temperature, humidity and population density, Taiwan has epidemics of dengue every year. Dengue is not only an environmental disease but also an important vector-borne disease around the world. An epidemic of vector-borne disease needs the co-existence of pathogen, vulnerable host and vector. Since there are no effective medicine and protective vaccine available for dengue currently, we could only suppress the mosquito population density by carry out Integrate Vector Control which is Source Reduction first and spraying insecticides subsidiary later, ordinarily. While in dengue outbreak, Taiwan local government will conduct emergency spray operation immediately to control the epidemic in a short time for resident health concern.

A successful chemical control program is composed of three factors: efficient sprayer, effective insecticide and skillful technician. Fog and Ultra-Low Volume (ULV) sprayers are applied to do Space Spray usually. This study selected several Fogs (fifteen models with thirty kinds of spraying combinations) and ULVs (fourteen models with forty five kinds of spraying combinations.) which often used to do Space Spray in southern Taiwan, and examined their efficacy by nebulization efficiency and flow rate stability. The results could provide epidemic prevention technicians to conduct precise spraying and raise the efficiency of chemical control.

Results showed that there were 50% of ULV models (7/14) had unstable flow rate, the ratio was higher than Fog models (20%, 3/15). The droplets size of most of the ULV models was fit in the Space Spray request. Only 7.1% of ULVs models (1/14) had over large droplets and the ratio was lower than Fog models (33.3%, 5/15). Generally, Fogs had relatively stable flow rate and poor nebulization efficiency than ULV. Stability of flow rate may relate to the conformation of sprayer and the nebulized efficiency has close relationships with their operate principles or types of nozzle. The efficacy of sprayer seems to have nothing to do

with its power but is associated with the quality control of the manufactory where it was made from.

Key words: dengue, space spray, sprayer, nebulization, flow rate

Introduction

According to the statistical data from World Health Organization (WHO), there are 50% of global population lived in the areas with epidemic of dengue, and it is estimated that there were approximately 100 million dengue infections and 500 thousand dengue hemorrhagic fever cases every year [1]. Warm climate, geographical features, human activity and the cross transmission of four serotypes of dengue virus resulted in severe epidemic of dengue in Southeast Asia. Taiwan is located in the border between the subtropical and tropical zones. With high population density, temperature and humidity, Taiwan is an area with high risk of vector-borne disease epidemics. For the last twenty years, southern Taiwan had several severe outbreaks of dengue and it was a nightmare of local residents.

Dengue fever is an environmental disease which happens in community with numerous mosquitoes breeding sites, such as flower vases, pots and waste tires, etc. These supply the habitat of mosquitoes to increase their population density and raise the risk of dengue epidemic. Since there are no effective medicines and protective vaccines for dengue currently, we could only suppress the mosquito population density by carrying out Integrate Vector Control which is Source Reduction first and spraying insecticides later, ordinarily. Government appeals to residents should clean out their living environment and get rid of water containers around the neighborhood for preventing dengue epidemics. While in outbreaks, we could only conduct chemical control by emergency spray with insecticides around the possible activity and living district of the suspected case to reduce the population density of mosquitoes and interrupt the transmission of dengue to protect residents health as soon as possible [2]. The principle of "Limited Spray" is to minimize the frequency and range of spraying, only the activity areas and residences of dengue confirmed cases need to be sprayed with insecticides. We need to advance our technique and quality of spray to carry out efficient dengue control and achieve the ultimate goal of public health protection.

Chemical control is to use insecticides to eliminate vectors immediately. Traditionally, spray methods were divided into two types: Space Spray and Residual Spray, by the different ecology of vectors, the formations of insecticides and the types of sprayers. Space Spray is using sprayers to spray the insecticide into air and kill the flight pests (e.g., mosquitoes and flies). Its advantages are easy-using, time-saving, effort-saving and overall efficiency, but the disadvantages are short-effect (only several hours) and droplets are so tiny that could be inhaled easily and harm the olds and children. In contrast, Residual Spray is to spray insecticide on the objects surface and to kill crawling pests (e.g., ants and cockroaches) when they were resting on it. The advantage of Residue Spray is long-effect for each spray, but the disadvantage is the slow-release effect which caused accidental eaten by children and pets and results injuries easily.

A successful chemical control can be attributed to three factors: efficiency sprayer, effective insecticide and skillful technician [2]. Skillful technician is the most important factor but easily neglected; besides, different spray methods need to apply the most suitable sprayer to get the best control efficacy. Sprayers used for chemical control are classified into four types by the principles of spraying: Hand-pressed sprayer, Motorized sprayer, Fog and Ultra-Low Volume (ULV) generally. Hand-pressed sprayer is to spray the insecticides by atmospheric pressure which can crush the solution into coarse droplets and the diameters are usually greater than 100 micrometers (μm). Motorized sprayer is to spray the insecticides by strong air stream which can break the solution into fine droplets and the diameters are usually larger than 50μm. Fog is using high temperature to vaporize the insecticide solution and the droplet size becomes smaller than 20μm, generally. ULV is to produces a cyclone and results the diameters of droplets are less than 50μm by centrifugal force.

With advances in technology and improvements on precision of instruments, the researches for droplet sizing have made a highlight recent progress. The size of droplets will affect the suspension time and drifting distance in the air, droplets within 20 to 50 μm diameter are appropriate for Space Spray [3]. Droplets with diameter larger than 50 μm will decrease the control efficiency of Space Spray since the gravity result them cannot suspend in the air for a long time and kill flight pests by continuous contact. But, droplets with diameter smaller than 20 μm are easily expelled by the flight airflow resulted from wing ventilation of flight pests and reduce the control efficiency too [4,5]. Different types of sprayers have their specific characters and are applicable for various situations [6]. Droplets sprayed by Hand-pressed and Motorized sprayer are usually larger than 50 μm in diameter will settle down to the ground during 2 to 3 minutes. In contrast, Fog and ULV can spray smaller droplets which are less than 50 μm generally and will suspend in the air for 2 to 3 hours. WHO recommend the latter two types of sprayers are appropriate for Space Spray [6,7].

Different spray methods would affect the speed of insecticide resistance development. The develop speed of insecticide resistance is closely related to the contacting time and the dosage of insecticides sprayed for vector control. Concept of Residual Spray is to kill the crawling pests with continuous contact for a period of time while they were resting on the sprayed surface. The crawling pests need to against the killing mechanism of insecticides strongly to survive, so the resistance will develop fast. In contrast, Space Spray is using fine droplets which can suspend in the air to kill flight pests. Since the contacting time of Space Spray is shorter and the dosage is lower, the develop speed of resistance will be relative slower than Residual Spray. With no residual effects, no contamination to furniture or household and low risk of insecticide resistance developed, Space Spray would be the better way to kill adult mosquitoes at present.

The efficacy of sprayer is influenced by its power stability and nebulized efficiency [8,9]. Increasing the pressure or changing the opening degree of flow regulating-valve will raise the flow rate and affect the size of nebulized droplets [10,11]. The types or caliber of nozzles could affect the size of droplets sprayed and its distribution in the air [12]. Researches confirmed, the spray amount of insecticides, concentration used to spray, droplet sizes and its suspending or drifting time were very important technical indices for nebulized efficiency evaluation [13,14,15]. Through the studies of droplets sizing and its distribution in the air for suspension or drifting, we could not only to redefine the Space Spray and Residual Spray, but also broaden the new horizons of vector control.

A very important concept for dengue chemical control is to conduct Space Spray at indoor and outdoor around the activity areas and residences of confirmed cases at the same time with Fog or ULV to kill the infected mosquitoes. The efficacy of sprayer will influence the spraying schedule and the efficiency of large-scale spraying operation. Sprayers with poor performance or maintenance will decrease the control efficiency and results to repeat spraying. It would cause the raise of the public anger, environmental pollution and insecticide resistance developed [16]. Fortunately, with accurate spraying technique, correct dilution process and appropriate concentration used we could still have certain control efficiency against the resistant strain of mosquitoes [2,17].

There are many brands and models of sprayer used for chemical control in Taiwan, currently. As for Fog, most of them were made in Germany and Korea, the market share was about 33.3% for each. Second one was USA, about 20% and the least were Britain and Taiwan. As for ULV, most were made in USA and the market share was about 33.3%, second one was Germany about 20% and the following were China, Korea and Taiwan sequentially. Fifteen Fogs and fourteen ULVs with various spraying combinations (power, nozzle caliber and degree of regulating-valve) often used for dengue control in Taiwan were selected to examine their flow rate and nebulized efficiency in order to comprehend their characters and advance the spraying technique for raising the control efficiency.

Materials and Methods

1. Sprayers

Examined sprayers were bought by Taiwan Centers for Disease Control (Taiwan CDC) during 2006 to 2011. They were generally applied to conduct Space Spray for dengue control by Bureaus of Health or Environmental Protection and Pest Control Operation companies in Taiwan. Selected sprayers including fifteen Fogs with thirty kinds of spraying combinations (power and nozzle caliber) and fourteen ULVs with forty five kinds of spraying combinations (power and degree of regulating-valve).

2. Flow Rate

In theory, the droplet size of sprayers will be affected by quantity, density and viscosity of insecticides solution [18,19]. But insecticides will be diluted by dozens, hundreds or even thousands folds of water while spraying, so the quantity of active ingredients in the sprayed solution is such a trace that can be neglected in practice and the droplet size will be no different with water-spraying. As reasoned, we used pure water instead to avoid the impurity interference and the results could analogize to chemical control practically [20].

Sprayers were inspected and warmed up before test to ensure their normal performance and the delivery system is anhydrous. Fixed amount of water was added into the insecticide tank and sprayed for 3 or 2 minutes for Fog and ULV individually. After sprayed, the remaining amounts of water in the tank were measured by consumption method. Experiments were repeated three times to obtain the average flow rate and the coefficient of variance (CV) was calculated.

3. Nebulization Efficiency

A. Test Preparation in Droplet Sizing Room

Droplet Sizing Room needs to keep clean and dark. Temperature and humidity should be kept at 25±1^{o}C and 60±5% separately at all times. Before and after each test, the room should be ventilated for 30 minutes to avoid the impurity in the air would interfere the accuracy of the Droplet Sizing Test.

B. Droplet Sizing

Spraying with 30 degree angle, droplets were measured at 50 centimeters distance away from the spray nozzle by Sizing Master (LaVision Inc.). Each kind of spraying combination was examined and repeated three times. Droplet parameters were analyzed (Table 1), including the Span and DR value [20].

Table 1. Definitions of droplet size parameters

Parameters	Definition
Numbers	total number of droplets measured during the test
D_{10} (NMD)	number median diameter, a diameter which divides the total number of droplets into two equal parts
DV_{10}	10% of the droplets have a diameter less than this value
DV_{50} (VMD)	volume median diameter, 50% of the droplets have a diameter less than this value
DV_{90}	90% of the droplets have a diameter less than this value
Span	$(DV_{90} - DV_{10}) \div DV_{50}$
DR(Diffusion Coefficient)	$D_{10} \div DV_{50}$

4. Statistical Analysis

A. Flow Rate

The CV value of the flow rate was smaller than 5 meant the sprayer has a stable flow rate. On the contrary, CV value of the flow rate was larger than or equal to 5 meant the spraying volume per unit of time for the sprayer will be suddenly large or small and caused the flow rate unstable.

B. Nebulization Efficiency

The Span value was smaller than 2 and the DR value was closed to 1 meant the nebulized efficiency of the sprayer was performed well, the droplets size were consistent and their distribution is uniform and in accordance with the normal distribution. On the contrary, if the Span value was larger than or equal to 2, or the DR value was smaller than or equal to 0.7 meant the nebulized efficiency of the sprayer was not well, the droplets size was inconsistent and did not meet the normal distribution.

Results

1. Flow Rate

A. Fog

The flow rates of fifteen Fogs with thirty kinds of spraying combinations were measured and listed in Table 2. There were 20% (3/15) of models and 16.7% (5/30) of spraying combinations had unstable flow rates. The CV values of SN-50A with nozzle caliber: 1.0 μm, 2762 with Low, Med and High level of regulating-valve and TF-34 with nozzle size: 0.8 μm was higher than 5 respectively and it meant that the flow rates of them were unstable. Besides, the other sprayers' CV values were less than 5 meant their spraying volume per unit of time were consistently.

B. ULV

The flow rates of fourteen ULVs with forty five kinds of spraying combinations were measured and listed in Table 3. There were 50.0% (7/14) of models and 46.7% (21/45) of spraying combinations had unstable flow rates. The CV values of 2600 with 1/4 and 1/2 circle of Regulating-valve, NEBULO with 1/2 and 1 circle of Regulating-valve, 2734 with Low and Max level of Regulating-valve, COLT with nozzle #16, Portastar with nozzle #45, #58 and #84, Twisiter XL with nozzle #19 and #28 and Starlet with nozzle LV62, 68, 74, 100,120 and ULV62,68,74,100 were higher than or equal to 5, respectively, and it meant that their flow rates were unstable. Besides, the other sprayers' CV values were less than 5 meant their spraying volume per unit of time were consistent.

There were 34.5% (10/29) of models and 34.7% (26/75) of spraying combinations in all measured sprays had unstable flow rates. Those need to be well maintained, regular examined and pay more attention at its performance while spraying to ensure the epidemic prevention operation could carry out smoothly.

2. Nebulization Efficiency

A. Fog

The droplet size parameters of fifteen Fogs with thirty kinds of spraying combinations were analyzed and listed in Table 2. According to the results showed that, values of D_{10} and DV10 were 12.8 to 30.0 and 9.8 to 24.4 μm respectively for all examined Fogs. Most of the values of DV_{90} for all examined Fogs were 18.1 to

54.0 μm except for K10 with nozzle caliber: 1.0 μm, TF-35 with nozzle caliber: 1.0 μm, DH99, SN-50A with nozzle caliber: 0.8 μm and H-2.4 with nozzle caliber: 6.0 μm those were much larger than 50 μm. The droplet sizes sprayed by most examined Fogs were 20 to 50 μm and were appropriate for space spray.

Table 2. Efficacy of Fogs

Sprayer Model	Nozzle Caliber (μm)/ Degree of Regulating-valve	Flow Rate(ml/min)	CV	Droplet Size(μm)				Span	DR
				D_{10}	DV_{10}	DV_{50}	DV_{90}		
K10	0.8	196.7±5.8	2.9	25.5	20.5	27.5	46.6	0.9	0.9
	1.0	302.2±7.7	2.5	26.8	23.1	45.7	99.5	1.7	0.6
TF35	0.8	166.7±6.2	3.7	25.9	21.0	26.7	35.3	0.5	1.0
	1.0	250.0±8.2	3.6	19.0	15.5	19.7	98.9	4.2	1.0
	1.2	308.3±12.5	4.1	25.8	20.8	27.3	39.0	0.7	0.9
	1.4	451.7±12.5	2.8	25.8	20.7	27.7	40.8	0.7	0.9
DH-99	—[1]	27.8±0.8	2.9	25.5	21.0	31.0	99.1	2.5	0.8
AR35	0.8	173.3±9.4	0.1	18.1	14.9	17.9	22.5	0.4	1.0
	1.0	273.3±9.4	0.0	19.8	16.3	19.4	25.5	0.5	1.0
	1.2	346.7±5.8	0.0	24.3	20.4	24.1	32.7	0.5	1.0
AR9	0.8	116.0±6.0	0.0	22.1	17.8	21.7	33.5	0.7	1.0
	1.0	203.0±6.6	4.8	23.4	18.7	23.5	35.6	0.7	1.0
	1.4	297.0±4.1	0.0	22.8	18.2	22.5	43.0	1.1	1.0
2762	Low[2]	24.2±2.4	9.9	24.8	19.7	27.1	41.3	0.8	0.9
	Med[2]	41.7±4.7	11.3	25.6	20.0	29.5	47.4	0.9	0.9
	High[2]	80.0±4.1	5.1	26.4	20.8	30.4	50.0	1.0	0.9
F39	—[1]	710.0±27.3	3.8	20.3	16.3	27.0	32.8	0.6	0.8
F25	—[1]	858.3±20.3	0.0	22.8	18.3	23.7	33.6	0.6	1.0
SN-50A	0.8	175.0±4.1	2.3	23.1	18.6	27.7	98.8	2.9	0.8
	1.0	308.3±23.6	7.7	25.8	20.6	29.2	53.1	1.1	0.9
	1.2	430.0±8.2	1.9	26.2	21.1	29.0	45.6	0.8	0.9
2000	—[1]	29.1±1.2	0.0	30.0	24.4	30.4	42.4	0.6	1.0
AV-520	—[1]	362.7±2.4	0.0	22.2	18.4	22.0	29.1	0.5	1.0
TF34	0.8	173.3±9.4	5.4	23.0	18.3	25.3	47.6	1.2	0.9
	1.0	273.3±9.4	3.4	24.1	18.9	29.2	54.0	1.2	0.8
20S	—[1]	376.7±2.4	0.6	27.6	22.4	29.0	41.8	0.7	1.0
55S-M	—[1]	746.7±12.5	1.7	23.8	18.9	25.8	44.3	1.0	0.9
H-2.4	2.0	531.7±16.1	3.0	12.8	9.8	12.7	18.1	0.7	1.0
	4.0	636.7±28.9	4.5	13.3	10.2	13.9	23.1	0.9	1.0
	6.0	740.0±20.0	2.7	13.6	10.4	15.1	98.1	5.8	0.9

1: fixed, not adjustable and original manufactory does not provide the data of the nozzle caliber

2: three-stage adjustment and original manufactory does not provide the data of the regulating-valve opening degree

Table 3. Efficacy of ULVs

Sprayer Model	Nozzle Caliber (μm)/ Degree of Regulating-valve	Flow Rate(ml/min)	CV	Droplet Size(μm)				Span	DR
				D_{10}	DV_{10}	DV_{50}	DV_{90}		
2600	1/4 of a cycle	1.0±0.1	9.6	19.8	16.1	20.9	57.3	2.0	1.0
	1/2 of a cycle	16.1±1.0	6.2	23.6	18.7	25.3	37.4	0.7	0.9
	3/4 of a cycle	40.4±0.8	2.5	22.3	18.5	22.1	28.8	0.5	1.0
	1 of a cycle	73.0±2.0	2.7	23.8	19.3	24.4	33.6	0.6	1.0
NEBULO	1/2 of a cycle	3.9±0.3	7.7	27.3	22.0	29.7	43.5	0.7	0.9
	1 of a cycle	17.1±1.2	7.0	27.9	22.4	30.6	47.4	0.8	0.9
	2 of a cycle	26.7±0.6	2.2	28.0	22.3	31.1	53.3	1.0	0.9
	10.5 of a cycle	220.8±2.9	1.3	27.6	22.1	30.6	56.1	1.1	0.9
TP-1000	1.5mm	67.7±2.0	3.0	24.0	18.9	25.6	54.8	1.4	0.9
2734	Low[1]	233.3±23.6	10.1	19.2	16.1	19.1	27.4	0.6	1.0
	Med[1]	293.3±9.4	3.2	22.2	18.2	23.0	28.9	0.5	1.0
	Max[1]	366.7±23.6	6.4	23.8	19.3	24.4	30.7	0.5	1.0
2794	Low[1]	127.5±2.7	2.1	20.8	16.7	21.4	39.2	1.1	1.0
6208	Med[1]	203.3±3.1	1.5	22.9	18.9	22.9	30.7	0.5	1.0
	Max[1]	267.9±3.9	1.5	24.1	19.4	24.8	33.5	0.6	1.0
	Low[1]	69.2±1.2	1.7	20.3	16.8	19.9	25.2	0.4	1.0
	Med[1]	124.2±1.2	1.0	23.7	19.7	23.5	29.5	0.4	1.0
	High[1]	162.5±2.0	1.2	25.2	20.4	26.8	40.2	0.7	0.9
COLT	#16[2]	48.3±4.7	9.7	21.3	16.8	21.8	29.9	0.6	1.0
	#22[2]	96.7±2.4	2.5	21.4	17.5	22.1	30.0	0.6	1.0
	#24[2]	103.3±4.7	4.6	24.8	20.2	25.3	32.0	0.5	1.0
Portastar	#45[2]	28.8±3.1	10.8	25.7	20.7	28.0	37.1	0.6	1.0
Twisiter XL	#58[2]	38.3±2.0	5.2	27.4	22.3	30.4	52.0	1.0	1.0
	#84[2]	75.0±8.2	10.9	28.5	22.7	32.2	54.5	1.0	1.0
	#19[2]	38.3±4.7	12.3	19.8	16.2	20.0	26.3	0.5	1.0
	#28[2]	93.3±4.7	5.0	21.8	18.0	21.7	29.3	0.5	1.0
	#36[2]	141.7±6.2	4.4	24.0	19.6	24.5	33.5	0.6	1.0
E-5	—[3]	86.7±0.0	0.0	32.8	27.6	32.6	52.3	0.8	1.0
TD55	—[3]	586.7±12.6	2.1	22.5	18.1	23.2	31.7	0.6	1.0
5CD	Yellow[1]	36.0±0.0	0.0	29.5	24.8	29.9	50.4	0.9	1.0
	Red[1]	45.3±1.9	0.0	30.3	25.6	31.1	148.1	3.9	1.0
	Black[1]	31.3±0.9	0.0	29.9	25.3	29.6	49.8	0.8	1.0

Continue table 3

Sprayer Model	Nozzle Caliber (μm)/ Degree of Regulating-valve	Flow Rate(ml/min)	CV	Droplet Size(μm)				Span	DR
				D_{10}	DV_{10}	DV_{50}	DV_{90}		
3000	Low[1]	98.3±2.9	3.0	22.4	17.8	23.5	36.7	0.8	1.0
	Med[1]	191.7±7.6	4.0	22.7	18.2	24.0	40.0	0.9	1.0
	Max[1]	246.7±5.8	2.3	23.1	18.2	24.8	40.9	0.9	0.9
Starlet	62 (ULV)[2]	31.7±2.9	9.1	18.2	14.7	18.0	23.2	0.5	1.0
	62 (LV)[2]	35.0±8.7	24.7	18.6	15.0	18.3	23.7	0.5	1.0
	68 (ULV)[2]	3.05±5.0	14.3	20.4	16.2	21.2	34.6	0.9	1.0
	68 (LV)[2]	40.0±10.0	25.0	18.9	15.1	18.8	24.3	0.5	1.0
	74 (ULV)[2]	46.7±5.8	12.4	19.6	16.3	19.0	27.3	0.6	1.0
	74 (LV)[2]	41.7±2.9	6.9	19.2	15.5	19.1	26.1	0.6	1.0
	100(ULV)[2]	65.0±5.0	7.7	20.1	16.3	19.0	27.3	0.6	1.1
	100 (LV)[2]	70.0±5.0	7.1	18.8	14.9	19.1	25.4	0.6	1.0
	120(ULV)[2]	73.3±2.9	3.9	21.9	18.1	21.9	30.3	0.6	1.0
	120(LV)[2]	85.0±10.0	11.8	22.0	17.8	22.3	30.9	0.6	1.0

1：three-stage adjustment and original manufactory does not provide the data of the regulating-valve opening degree
2：model of nozzle and original manufactory does not provide data of the nozzle caliber
3：fixed, not adjustable and original manufactory does not provide the data of the regulating-valve opening degree

The value of Span for K10 with nozzle caliber: 1.0 μm was 1.7 (＜2) meant the distribution of droplet size was normal and DR value was 0.6 (＜0.7) meant the droplets sizes were vary greatly. Due to the value of DV_{90} was 99.5μm (>50) meant K10 with nozzle caliber: 1.0 μm tended to spray large particles. Value of Span for TF-35 with nozzle caliber: 1.0 μm, DH99, SN-50A with nozzle caliber: 0.8 μm and H-2.4 with nozzle caliber: 6.0 μm was 4.2, 2.5, 2.9 and 5.8 respectively and were all larger than 2. DR values for above four Fogs with four spraying combinations were 1.0, 0.8, 0.8 and 0.9 respectively and were all close to 1. The values of DV_{90} for them were 98.9, 99.1, 98.8 and 98.1 respectively and were all larger than 90 μm. It meant that the distribution of droplets size were abnormal but were about the same large size particles for above four Fogs with four spraying combinations.

For examined Fogs, there were 33.3% (5/15) of models and 16.7% (5/30) of spraying combinations had poor nebulization efficiency such as their larger particles sprayed and abnormal distribution of droplets size. In addition, most of examined Fogs had well nebulization efficiency (Span<2 and DR≈1) and appropriate to do Space Spray for killing flying mosquitoes.

B. ULV

The droplet size parameters of fourteen ULVs with forty five kinds of spraying combinations were analyzed and listed in table 3. Results showed that, the values of $D_{10,10}$ and DV_{50} were 18.2 to 32.8, 14.7 to 27.6 and 18.0 to 32.6 µm individually for all examined ULVs. Only the value of DV_{90} for 5CD with Red-Regulating-valve was 148.1 µm, others were 23.2 to 57.3 µm. It meant that most of the examined ULVs sprayed appropriate droplet sizes which were 20 to 50 µm and were applicable for Space Spray.

Except for 5CD with Red-Regulating-valve' Span value was 3.9 (>2), others were all small than 2 meant the distribution of droplets size for most of the examined ULVs were uniform and in accordance with the normal distribution. Besides, each value of DR for all tested ULVs was 0.9 to 1.0 (close to 1) it meant the droplet sizes sprayed by fourteen ULVs with 45 kinds of spraying combinations were consistence.

Although there were 7.1% (1/14) of models and 2.2% (1/45) of spraying combinations had poor nebulization efficiency, most of examined ULVs were proper to do Space Spray since their droplets size were consistent and fitted normal distribution.

Since there were 34.4% (10/29) of models had unstable flow rates and 34.7% (26/75) of spraying combinations had over size (larger or smaller) droplets and abnormal distributions for twenty nine sprayers with seventy five kinds of spraying combinations examined. We have to maintain every sprayer thoroughly before operating and measure the droplet size regularly to ensure its quality of spraying. But most of the sprayers were performed well and were applicable to carry out Space Spray for dengue control in Taiwan at present.

Discussions

There were 20.0% (3/15) of Fogs and 50.0% (7/14) of ULVs examined had unstable flow rates evident the stability of ULV is greater than Fog generally. Usually, the stability of the spraying volume per unit of time for the sprayer relates to its Motor Power or Pressure. Power is defined as the Work per unit of time (P=W/t). As have same Work, sprayer with larger Power can accomplish task in a shorter time i.e., spray more volume per unit of time. But in this study, there seems to have no relationship or tendency between the flow rate and its value of CV. Therefore, we speculate the stability of flow rate has nothing to do with its Power but may relate to the conformation of sprayer.

According to the results of nebulization efficiency test, there were 16.7% (5/30) of spraying combinations in examined Fogs and only one (2.2%, 1/45) spraying combination in examined ULVs had poor nebulized efficiency. Apparently, ULVs had better nebulized efficiency than Fogs. Nebulized efficiency of a sprayer was determined by the values of Diffusion Coefficient (DR) and Span but unrelated to its Power. The spraying principle of Fog is to produce high temperature by pulse engine and vaporize insecticide solution into tiny particles. Since pulse engine generates power by batches of combustions and the insecticide solution may be heated unevenly would cause vary extent of vaporization and result in inconsistent of the droplets size to affect the nebulization efficiency. Besides, the spraying principle of ULV is producing a cyclone to crush the insecticide solution into fine particles by centrifugal force. Because the centrifugal force would be sustain and stable to affect the insecticide solution homogeneously, therefore the droplets size may be uniformed and led to well nebulized efficiency of ULV.

Through the result of nebulization efficiency test, we found the sprayer combinations of Fogs with larger or smaller nozzle calibers had poor nebulized efficiency. The size of nozzle calibers may be one of the factors that would affect Fogs' nebulization efficiency. Except for 5CD with Red-Regulating-valve had poor nebulized efficiency other ULVs were performed well. Since 5CD was the only one of examined ULVs which equipped with cone-nozzle others were with fan-nozzle. Therefore the type of nozzle calibers may be one of the factors which would affect ULVs' nebulization efficiency.

Most of the sprayers which conduct Space Spray for dengue control in Taiwan were manufactured in Germany, USA, England, Korea, China and Taiwan respectively. Among the ten sprayers (1/3) which had unstable flow rates of all examined sprayers, six were from Germany and four were from USA. Besides, there were six sprayers (1/5) had poor nebulized efficiency of all examined, four of them was made in Germany and the other two were made in Korea and China separately. The difference of the performance of a sprayer such as flow rate and nebulized efficiency may be resulted from the level of quality control required of its original manufactory.

Examined sprayers were brand-new and bought during 2006 to 2011 by Taiwan CDC. Since each manufactory might have its own requirements of quality control and each sprayer had different characters, even same label and same model but different sprayers might have different performances. Besides, operating habits of technician, maintained frequency and preservation method would affect the sprayer performances too. Results in this study may have some limitation when analogize to other situations. According to the results of this study, we found out that most of the examined twenty nine sprayers with seventy five kinds of spraying combinations had well performances. Only very small portion of examined sprayers had unstable flow rates or poor nebulization efficiency. With proper operation method, thoroughly regular maintenance and pay attention to its performance while spraying at all times, all models of examined Fogs and ULVs could applied to Space Spray for control the mosquitoes of dengue efficiently. Furthermore, skillful technician with advance spraying technology could raise the quality of spraying operation and increase the efficacy of epidemic control. In the future, if we can investigate the tested data of sprayer efficacy with different brand and model about and construct a data bank for category search and classification recommendation by Excel program, it could provide to governments for purchasing excellent sprayers and make epidemic preventive technicians easy to select the most appropriate spraying combinations in order to save public treasury and upgrade the efficacy of public health intervention.

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Outbreak Investigation Express

Investigation on the First Imported Rabies Case in 2013

Yen-Chang Tuan, Min-Nan Hung, Mei-Fang Chuang, Hui-Chen Lin,
Ying-Ying Tsai, Mei-Ju Chen, Chiou-Yueh You, Chao-Ching Chang

Kaohsiung-Pingtung Regional Center, Centers for Disease Control,
Ministry of Health and Welfare, Taiwan

Abstract

On May 10, 2013, a medical center in Kaohsiung reported a suspected rabies case. The patient was a Filipino laborer who arrived in Taiwan on April 7, 2013. He started complaining pain in his right hand on May 3. By May 9, he had gradually developed nausea, vomiting, loss of appetite, sore throat, fever, conscious disturbance, generalized weakness, right hand twitches, and unsteady gait. He was seen by physicians in four different medical establishments in Pingtung. On May 9, he went to the emergency of a medical center in Kaohsiung, and was found to have high fever, slurred speech, conscious disturbance, multiple organ failure, and healed bite marks were observed on his right middle finger and inner thigh. His family indicated that the patient was bitten by a dog on March 10, 2013, while he was still in Cagayan, the Philippines, but did not seek medical attention following the incident. On May 10, physicians at the hospital reported the patient as a suspected rabies, and then was confirmed by the Research and Diagnostic Center of the Centers for Disease Control. The patient died on May 25. In accordance to the Rabies Manuel, case investigation and contact risk assessment were conducted. There were 15 contacts at the factory, 37 at the medical center, and 7 in other healthcare establishments. Post-exposure prophylaxis was given to 10 persons, but only 9 persons completed prophylactic treatment. Rabies in humans is very rare in Taiwan. The experience from this case may serve as a reference for future rabies control.

Keywords: rabies, questionnaire, contacts, incubation period

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