

## Permethrin Content in Textiles Affecting Mosquito Repellency Efficiency

Kai-Chiu Ho<sup>1\*</sup>, Song-Ying Mo<sup>1</sup>, Tai-Yu Wong<sup>2</sup>, Lok-Sze Tsui<sup>3</sup> and Manni Mo<sup>4</sup>

<sup>1</sup>Zhijiang College of Zhejiang University of Technology, P.R. of China.

<sup>2</sup>Hansk New Materials Holdings Ltd., Hong Kong.

<sup>3</sup>Department of Chemical and Biological Engineering, The Hong Kong University of Science and Technology, Hong Kong.

<sup>4</sup>Biodesign Institute, Arizona State University, USA.

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### \*Correspondence:

Kai-Chiu Ho, Zhijiang College of Zhejiang University of Technology, No. 958, Yuezhou Avenue, Keqiao, Shaoxing City, P.R. China.

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### ABSTRACT

Permethrin is one of the most common active ingredients in mosquito repellents. It is so commonly utilized to spray textiles and clothing repelling insects, in particular, mosquito, in order to avoid the vector-borne disease spreading through human society. In this article, our research team is, at first, to take research on two products, namely, Permethrin-based Mosquito Repellent Spray in aerosol version and water emulsion version respectively provided by Hansk New Materials Holdings Ltd., Hong Kong and identify which one is better anti-mosquito efficacy and longer durability. Then, the research team further prepares the test products: Permethrin-based Mosquito Repellent Sprays for textiles and clothing with three different recipes (with different permethrin content). We conduct experiments and testing to evaluate the functionality of each recipe. We also investigate the anti-mosquito efficacy of the textiles and clothing sprayed with such kinds of permethrin-based Mosquito Repellent Sprays respectively.

### Keywords

Permethrin, Efficacy.

### Introduction

People working or staying outdoor such as countryside, parks, forests, etc. would like to wear insecticide-treated clothing to project them away from blood feeding arthropods, i.e. mosquito. There are many products and technologies designed to prevent bites from arthropods and to reduce the risk for transmission of vector-borne pathogens. Permethrin is the most common active ingredients in mosquito repellents. They are so commonly adopted for spraying to clothing to repel insects, in particular, mosquito to avoid the vector-borne disease spreading through human society [1].

### Permethrin [2]

• Permethrin is an insecticide in the pyrethroid chemical family. The International Union of Pure and Applied Chemistry (IUPAC) name for permethrin is 3-phenoxybenzyl (1RS,3RS;1RS,3SR)-3-(2,2-dichlorovinyl)-2,2-dimethyl-cyclopropanecarboxylate and the Chemical Abstracts Service

(CAS) registry number is 52645-53-1 [3]. Permethrin is considered a type I pyrethroid [4].

- Permethrin was originally registered for use by the United States Environmental Protection Agency (U.S. EPA) in 1979, and it was re-registered in 2006 [5].
- Permethrin is a blend of two stereoisomers [3]. Details on the ratio used in a specific product may be listed on the label, or may not be readily available. For the remainder of this fact sheet, note that permethrin refers to an isomer blend and not one isomer alone.

### Physical / Chemical Properties

- Technical permethrin ranges from a colorless crystal to a yellow or brown viscous liquid [3,4]. No information on the odor of permethrin was found.
- Vapor pressure [3]:  $2.15 \times 10^{-8}$  mmHg at 20°C
- Octanol-Water Partition Coefficient (Kow) [3]: 6.1 at 20°C
- Henry's constant [4]:  $1.4 \times 10^{-6}$  atm·m<sup>3</sup>/mol
- Molecular weight [3]: 391.3 g/mol
- Solubility (water) [3,4]:  $5.5 \times 10^{-3}$  mg/L,  $6 \times 10^{-3}$  mg/L
- Soil Sorption Coefficient (Koc) [5]:  $1.00 \times 10^5$

## Uses

Permethrin can be used in public health mosquito abatement programs and on a variety of food or feed crops and livestock; or in structures and buildings, including livestock housing and food-handling establishments. Permethrin can also be used in numerous residential sites, both indoor and outdoor, and on pets and clothing. When permethrin is used on large areas like crops, nurseries, and sod farms it is considered a restricted use pesticide. For other applications, it is considered a general use pesticide. Formulations of permethrin used for treatment of head lice and scabies on humans are available, but these are considered pharmaceuticals, which are regulated by the United States Food and Drug Administration (FDA) [7]. Uses for individual permethrin products vary widely. Always read and follow the label when applying pesticide products.

## Mode of Action Repelling Mosquito

Permethrin acts on the nervous system of insects. It interferes with sodium channels to disrupt the function of neurons, and causes muscles to spasm, culminating in paralysis and death [2,3].

Permethrin is a broad-spectrum insecticide, a chemical used to kill a variety of insects. Permethrin is referred to as a synthetic pyrethroid insecticide because, while manmade, it resembles naturally-occurring chemicals with insecticidal properties, called pyrethroids. Pyrethroids are found especially in chrysanthemums. Pyrethroids are one of the oldest classes of organic insecticides known [7]. They work by quickly paralyzing the nervous systems of insects, producing a quick "knockdown" effect on insect pest populations. Permethrin acts as a stomach poison when it is ingested by insects or as a contact poison through direct contact with target pests. It kills adults, eggs, and larvae, and has a slight repellent effect against insects [8]. The insecticidal activity of this material lasts up to 12 weeks after application [9].

To investigate the anti-mosquito repellent efficacy and durability of two products provided by Hansk New Materials Holdings Ltd., Hong Kong (Hansk), namely

- (i) Permethrin-based Mosquito Repellent Spray in aerosol version; and
- (ii) Permethrin-based Mosquito Repellent in water emulsion version

The composition of the ingredients of each product are as follows: Permethrin-based Mosquito Repellent Spray in aerosol version (Repellent A)

Product Specification:

Best Use	Backpacking, Camping, Hiking
Active Ingredient	1.5 % Permethrin
Other Ingredients	18.5% Solvent 80% Hydrocarbon aerosol
Volume	100 fluid gram
Solution Form	Solvent-based Solution (for aerosol package)
Effective Duration	2 days

Permethrin-based Mosquito Repellent in water emulsion

## (Repellent B)

Best Use	Backpacking, Camping, Hiking
Active Ingredient	1.5% Permethrin
Other Ingredients	3% Surfactants 4.5% Solvents 90% Water 1% Preservative
Volume	100 fluid gram
Solution Form	Water-based Emulsion package
Effective Duration	7 days

## Fabric specimen Sprayed by Two Mosquito Repellent as 100% Cotton Knitted Fabric, around 150 gm/m<sup>2</sup>

100% cotton knitted fabric with 150 gm/m<sup>2</sup> is to select to act the specimen sprayed by Repellent A and Repellent B respectively because cotton fibre has good absorbency and capillary action to absorb mosquito repellent solution either they are in aerosol or water emulsion [10].

## Conduct Mosquito Repellent Efficacy Testing under National or Commercial Testing Standard and Protocol

Then, we explore whether there are commercial standards for conducting mosquito repellents efficacy test in order to guide us to conduct the tests in proper manners. Having scrutinized relevant information sources, we understand that there is no national, international or commercial standard except China has its own national standard and protocol for mosquito repellent efficacy [11]. Chinese Centre for Disease Control and Prevention is a sole organization authorized by Chinese Government to conduct mosquito repellent efficacy [12] testing under the Chinese Government Standards, including GB/T 13917.9-2009 "Laboratory Efficacy Test and Evaluation of Pesticide Registration Hygienic Insecticides Part 9: Repellents" and GB/T 30126-2013 "Testing and Evaluation of Mosquito Repellency Performance of Textiles" [12].

## The testing requirements are as follows Test Methods and Instructions

Testing Protocol: we refer to GB/T 13917.9-2009 "Laboratory Efficacy Test and Evaluation of Pesticide Registration Hygienic Insecticides Part 9: Repellents" and GB/T 30126-2013 "Testing and Evaluation of Mosquito Repellency Performance of Textiles" [12].

Fabric Sample Size: 6 pieces of Control fabric (100% of cotton knitted fabric) are without mosquito repellent solution; 3 pieces are sprayed by Repellent A; and 3 pieces are sprayed by Repellent B solution. They are cut in the size of A4 paper size and then are prepared for testing.

Sample Preparation with Repellents A & B [14]

- Shake the spray bottle of the said repellent before use;
- Lay the fabric sample on table or hang, ensure the fabric is clean and dry;
- Hold bottle 10-20 cm away and spray evenly on fabric sample. Make sure the fabric sample is treated thoroughly;

- Fabric should be dried without hairdryer; and
- Hang to dry, ensure textile is fully dry before Arm-in-Cage (AIC) testing; and
- All sprayed fabric samples are stored in a room at the temperature is  $26^{\circ}\text{C} \pm 1^{\circ}\text{C}$  and the relative humidity is  $64\% \pm 10\%$  for 1 day.

**Testing insect:** *Aedes albopictus* (*Aedes albopictus*), 7 days after emergence, haven't been blood bleeding, adult mosquito.

**Testing conditions:** the temperature is  $26^{\circ}\text{C} \pm 1^{\circ}\text{C}$  and the relative humidity is  $64\% \pm 10\%$ .

**Testing method:** AIC Test. AIC test is a quick and efficient way to investigate the efficacy of repelling substances against mosquitoes. This method is suited for the evaluation of topical repellents, like cremes, lotions and liquid formulations. Repellent impregnated textiles can also be evaluated within AIC test [14].

Female mosquito adults (about 60) of *Aedes albopictus* are placed in mosquito cage (Size: 33cm x 33cm x 33cm). 3 human testers take part in the test, and the human testers clean their hands before the testing. Each human tester wrap his/her fist in a control fabric and put it in a mosquito cage. The number of mosquitoes on the surface of the sample fabric is counted every 20 seconds. The test lasts 2 minutes. Subsequently, the human testers wrap their fists with mosquito repellent fabric and put them into mosquito cage. The same method is used to test and record the number of mosquito landing/biting. The repetition test data is to calculate the repellency rate [14,19]:

$$P = (N - K) / N * 100\%$$

In the form of:

P – repellency rate (%)

Testing Duration	Number of mosquito landing on Repellent A sprayed Fabric			Number of mosquito landing on control fabric (without sprayed with Repellent A)			Repellency Rate Average (%) of Repellent A
	Human Tester 1 (HT1)	Human Tester 2 (HT2)	Human Tester 3 (HT3)	Human Tester 1 (HT1)	Human Tester 2 (HT2)	Human Tester 3 (HT3)	$A_{RA} = \frac{\sum(P(HT1), P(HT2), P(HT3))}{3}$
12 hours	4	6	5	34	33	34	82.29
24 hours (1 day)	14	12	15	36	34	36	59.42
48 hours (2 days)	24	26	23	37	36	34	31.76
96 hours (4 days)	29	27	31	38	36	40	23.73
168 hours (7 days)	40	39	41	42	40	42	3.19
240 hours (10 days)	42	44	39	43	45	40	2.3
						$TA_{RA}$ :	33.78

**Table 2:** Mosquito Repellency Rate of Repellent A Sprayed Fabric Samples.

Referring to  $P$  (Repellency Rate (%)) =  $(N - K) / N * 100\%$  shown above:

$P(HT1)$ : Repellency Rate of Human Tester 1

$P(HT2)$ : Repellency Rate of Human Tester 2

$P(HT3)$ : Repellency Rate of Human Tester 3

$A_{RA}$ : Repellency Rate Average (%) of Repellent A is the Sum of Repellency Rate of 3 Human Testers on Repellent A divided by 3 (3 human testers) at each test duration;  $TA_{RA}$ : Total average (%) of  $A_{RA}$  is the sum of Repellency Rate Average (%) from different test durations divided by 6 (6 durations).

K – the total number of mosquito's land on mosquito repellent sprayed fabric.

N – the total number of mosquito's land on the control fabric.

### Analysis of the Mosquito Repellent Efficacy Testing Results

Chinese Centre for Disease Control and Prevention (CDC) is a sole organization authorized by Chinese Government to conduct mosquito repellent efficacy [13]. We have prepared 6 pieces of 100% cotton knitted fabrics per each repellent, i.e., 3 pieces treated fabrics and 3 pieces of untreated fabrics (control fabrics). Totally, there were 12 pieces of cotton knitted fabrics for CDC to conduct AIC Test.

Since two selected repellents has different lifetime on mosquito repellency efficacy, i.e. Repellent A has 2 days (48 hours) lifetime whereas Repellent B has 7 days (168 hours) lifetime, we choose the appropriate testing duration schedule to test the repellency rate of two repellents respectively as shown at Table 1:

Testing Duration	Sequence of Testing	Testing Method
12 hours (Hrs)	1st Test	AIC Test*
24 hours (1 day)	2nd Test	AIC Test*
48 hours (2 days)	3rd Test	AIC Test*
96 hours (4 days)	4th Test	AIC Test*
168 hours (7 days)	5th Test	AIC Test*
240 hours (10 days)	6th Test	AIC Test*

**Table 1:** Mosquito Repellent Testing Time Schedule

\*: 3 pieces of repellent treated fabrics and 3 pieces of control fabrics were continually utilized for the above sequence of testing.

After testing, CDC provided us the testing results and we summarized them as table format for analysis.

Testing Duration	Number of mosquito Landing on Repellent B Sprayed Fabric			Number of mosquito landing on control fabric (without sprayed with Repellent B)			Repellency Rate Average (%) of Repellent B
	Human Tester 1 (HT1)	Human Tester 2 (HT2)	Human Tester 3 (HT3)	Human Tester 1 (HT1)	Human Tester 2 (HT2)	Human Tester 3 (HT3)	$A_{RB} = \frac{\sum(P(HT1),P(HT2),P(HT3))}{3}$
12 hours	4	3	5	34	33	34	87.84
24 hours (1 day)	6	4	5	37	35	36	88.14
48 hours (2 days)	4	4	6	36	38	35	87.06
96 hours (4 days)	5	5	4	38	40	39	88.03
168 hours (7 days)	8	7	9	39	36	40	79.18
240 hours (10 days)	14	13	16	41	38	36	62.39
						$TA_{RB}$	82.10

**Table 3:** Mosquito Repellency Rate of Repellent B Sprayed Fabric Samples.

Referring to  $P$  (Repellency Rate (%)) =  $(N - K) / N * 100\%$  shown above:

$P(HT1)$ : Repellency Rate of Human Tester 1

$P(HT2)$ : Repellency Rate of Human Tester 2

$P(HT3)$ : Repellency Rate of Human Tester 3

$A_{RB}$ : Repellency Rate Average (%) of Repellent B is the Sum of Repellency Rate of 3 Human Testers on Repellent B divided by 3 (3 human testers) at each test duration;  $TA_{RB}$ : Total average (%) of  $A_{RB}$  is the sum of Repellency Rate Average (%) from different test durations divided by 6 (6 durations).

Referring to Table 2, the number of mosquito landing/biting on human testers' fist wrapped with fabric sprayed with Repellent A varies in proportion to test duration. Duration longer than 48 hours (two days), the mosquito repellency efficacy becomes invalid and has no repellency effect.

Referring to Table 3, the number of mosquito landing/biting on human testers' fist wrapped with fabric sprayed with Repellent B increases in proportion to test duration. Duration longer than 168 hours, the mosquito repellency efficacy still has over 62.39% with moderate repellency effect.

In accordance with the GB/T 30126-2013 "Testing and Evaluation of Mosquito Repellency Performance of Textiles" [12] of the Chinese Standard, the mosquito repellency efficacy ranking is as follows:

Mosquito Repellency Efficacy Ranking	A Grade	B Grade	C Grade
Repellency Rate (%)	> 70%	70% - 50%	<50%, >30%
Repellency Efficacy Effect	Excellent	Good	Moderate (has repellency effect)

**Table 4:** Mosquito Repellency Efficacy Ranking.

In comparison of Repellent A and Repellent B shown at Tables 2 to 4, we find out the mosquito repellency efficacy of Repellent B is excellent with high repellency rate up to 62.39% and longer repellency period (more than 168 hours). The clothing made up with the Repellent B sprayed fabric has very good mosquito repellency protection for wearer. Oppositely, Repellent A has lost its repellency efficacy after 2 days and has no repellency effect to hungry female *Aedes albopictus* adults.

## Discussion

In comparison of Repellent A and Repellent B shown at Tables 2 to 4, we find out the mosquito repellency efficacy of Repellent

B is excellent with high repellency rate up to 62.39% and longer repellency period (more than 7 days (168 hours)). The reasons are as follows:

### Comparison of Vapour Pressure of Repellent A and B

The chief solution made up for Repellent A is hydrocarbon aerosol, i.e. propane which vapour pressure is 7600 mmHg at 25.8°C [15] is highly volatile agent as compared with vapour pressure of water in 25.209 mmHg at 26°C [16]. In this circumference, while Repellent A is sprayed to the cotton knitted fabric, the hydrocarbon aerosol is instantly vaporized and leaves Permethrin small particles attaching to the fabric surface without less chances enable cotton fibres to absorb the aerosol containing permethrin. Therefore, the mosquito repellent efficacy and durability of the Repellent A would be deteriorated due to oxidation by air, moisture, light, etc. On the other hand, the Repellent B is sprayed to the cotton knitted fabric, its water emulsion containing Permethrin small particles is absorbed by cotton fibre due to its capillary action and hydrophilic property [17]. In this case, the mosquito repellent efficacy and durability of the Repellent B would be lasted longer time due to lower vaporization and oxidation of Permethrin by aforesaid environmental factors.

### Mixture of Surfactants of the Repellent B enable higher penetration of Permethrin particles to the cotton fibre inside

Hansk has taken a series of researches and finally formulated a mixture of surfactants and solvents which could control wetting and penetration rate of textile fibre by corresponding solutions [18]. The imbibition of textile fibre takes place as result of two processes:

a "Bulk" production, since the strands of yarn behave as an assembly of capillaries; and

a surface rise due to the formation of surfactant adsorption layers. Hansk has developed the Repellent B with the active ingredients of Permethrin and said surfactants. The mosquito repellent efficacy

62.39% shown at Table 4 meets B Grade shown at Table 4. This shown the improved recipe of Repellent B with water emulsion is much better than Repellent A in terms of repellent efficacy and durability.

### To investigate the Influence of Permethrin Content in relation with Mosquito Repellency Efficacy

The research team has taken researches on the permethrin content utilized on mosquito repellent spray. We found out that Permethrin is an insecticide that has applications as an insect repellent in low concentrations (0.5%) [10]. Permethrin repellents are sprayed directly on clothing and gear. It remains effective on fabrics for up to two weeks, even though laundering. Wearing permethrin-treated clothing will prevent up to 97% of mosquito bites [10].

The research team produced three kinds of recipes (various level of permethrin content) on their permethrin-based Mosquito Repellent Sprays for textiles fabric specimens as follows:

	Recipe A	Recipe B	Recipe C
Active Ingredient	3% Permethrin (3 gram)	4% Permethrin (4 gram)	5% Permethrin (5 gram)
Volume	100 fluid gram	100 fluid gram	100 fluid gram
Solution Form	Water-based Emulsion	Water-based Emulsion	Water-based Emulsion
Recipe Concentration in Terms of gm/litre (g/l)	30 g/l	40 g/l	50 g/l

**Table 5:** Preparation of Three Different Spray Recipes for Textiles Fabric Specimens.

Fabric specimen Sprayed by the three different recipes shown at Table 1 on 100% Cotton Knitted Fabric, around 150 gm/m<sup>2</sup>.

Conduct Mosquito Repellent Efficacy Testing under National or Commercial Testing Standard and Protocol.

Analysis of the Mosquito Repellent Efficacy Testing Results.

**Table 6:** Mosquito Repellency Rate of Three Different Recipes Sprayed on Fabric Specimens (a) Results of Recipe A, (b) Results of Recipe B; and (c) Results of Recipe C.

Testing Duration	Number of mosquito landing on Recipe A sprayed Fabric			Number of mosquito landing on control fabric (without sprayed with Recipe A)			Repellency Rate Average (%) of Recipe A
	Human Tester 1 (HT1)	Human Tester 2 (HT2)	Human Tester 3 (HT3)	Human Tester 1 (HT1)	Human Tester 2 (HT2)	Human Tester 3 (HT3)	RA <sub>RA</sub>
0 week	8	9	10	35	33	36	75.33
4th week	12	10	13	36	38	37	68.40
8th week	15	13	14	37	34	36	60.77
12th week	20	17	18	37	38	36	50.00
16th week	29	30	28	37	35	40	21.66
						TRA <sub>RA</sub>	55.23

Referring to P (Repellency Rate (%)) = (N- K) /N \* 100% shown above:

P(HT1): Repellency Rate of Human Tester 1

P(HT2): Repellency Rate of Human Tester 2

P(HT3): Repellency Rate of Human Tester 3

RA<sub>RA</sub>: Repellency Rate Average (%) of Recipe A is the Sum of Repellency Rate of 3 Human Testers on Recipe A divided by 3 (3 human testers) at each test duration

TRA<sub>RA</sub>: Total average (%) of RA<sub>RA</sub> is the sum of Repellency Rate Average (%) from different test durations divided by 5 (5 durations)

Testing Duration	Number of mosquito landing on Recipe B sprayed Fabric			Number of mosquito landing on control fabric (without sprayed with Recipe B)			Repellency Rate Average (%) of Recipe B
	Human Tester 1 (HT1)	Human Tester 2 (HT2)	Human Tester 3 (HT3)	Human Tester 1 (HT1)	Human Tester 2 (HT2)	Human Tester 3 (HT3)	RB <sub>RA</sub>
0 week	6	4	5	36	38	37	86.42
4th week	5	6	4	37	40	38	86.98
8th week	6	8	6	39	35	36	81.65
12th week	15	13	14	37	39	37	62.75
16th week	18	15	17	36	37	35	53.62
						TRB <sub>RA</sub>	74.28

Referring to P (Repellency Rate (%)) = (N- K) /N \* 100% shown above:

P(HT1): Repellency Rate of Human Tester 1

P(HT2): Repellency Rate of Human Tester 2

P(HT3): Repellency Rate of Human Tester 3

RB<sub>RA</sub>: Repellency Rate Average (%) of Recipe B is the Sum of Repellency Rate of 3 Human Testers on Recipe B divided by 3 (3 human testers) at each test duration

TRB<sub>RA</sub>: Total average (%) of RB<sub>RA</sub> is the sum of Repellency Rate Average (%) from different test durations divided by 5 (5 durations).

Testing Duration	Number of mosquito landing on Recipe C sprayed Fabric			Number of mosquito landing on control fabric (without sprayed with Recipe C)			Repellency Rate Average (%) of Recipe C
	Human Tester 1 (HT1)	Human Tester 2 (HT2)	Human Tester 3 (HT3)	Human Tester 1 (HT1)	Human Tester 2 (HT2)	Human Tester 3 (HT3)	RC <sub>RA</sub>
0 week	4	3	2	35	37	34	91.52
4th week	3	2	4	38	41	39	92.32
8th week	5	4	2	41	35	38	90.36
12th week	3	3	5	32	38	36	89.61
16th week	6	7	5	38	35	40	83.90
						TRC <sub>RA</sub> :	91.52

Referring to P (Repellency Rate (%)) = (N - K) / N \* 100% shown above:

P(HT1): Repellency Rate of Human Tester 1

P(HT2): Repellency Rate of Human Tester 2

P(HT3): Repellency Rate of Human Tester 3

RC<sub>RA</sub>: Repellency Rate Average (%) of Recipe C is the Sum of Repellency Rate of 3 Human Testers on Recipe C divided by 3 (3 human testers) at each test duration

TRC<sub>RA</sub>: Total average (%) of RC<sub>RA</sub> is the sum of Repellency Rate Average (%) from different test durations divided by 5 (5 durations).

### Analysis of the Mosquito Repellent Efficacy Testing of Three Different Spray Recipes

Recipe A with 3% Permethrin

Recipe B with 4% Permethrin

Recipe C with 5% Permethrin

In accordance with the GB/T 30126-2013 "Testing and Evaluation of Mosquito Repellency Performance of Textiles" [12] of the Chinese Standard, the mosquito repellency efficacy ranking is as follows:

In comparison of Recipe A, Recipe B, and Recipe C shown at Table 6, we find out the mosquito repellency efficacy of Recipe C (with 5% Permethrin) is excellent with high repellency rate up to 92% as compared with Recipe B (with 4% Permethrin) and Recipe A (with 3% Permethrin). The clothing made up with the fabric specimen sprayed Recipe C would have very good mosquito protection for wearer. Recipe A has lost its repellency efficacy after 16 weeks and may not have repellency effect to hungry female Aedes albopictus adults.

### Determination of the Pesticide Residues – Permethrin inside the Fabric Specimen

In accordance with the GB/T 18412.4-2006 "Textiles – Determination of the Pesticide Residues – Part 4 Pyrethroid Pesticides" [12] of the Chinese Standard, the residues of the Permethrin content inside the fabrics (similar fabric undergone Mosquito Repellency Efficacy Test) sprayed with Recipe A, B & C fabric specimen in the size of A4 paper size and the preparation arrangement is shown at Table 4. The sprayed fabric specimens have been prepared and evaluated by this standard as follows:

Testing Procedure of the GB/T 18412.4-2006 "Textiles – Determination of the Pesticide Residues – Part 4 Pyrethroid Pesticides" is shown below. We follow the procedures of the aforesaid standard to evaluate the permethrin residue in fabric

specimens shown at Table 7:

Testing Duration	Recipe A	Recipe B	Recipe C
Active Ingredient	3% Permethrin (3 gram)	4% Permethrin (4 gram)	5% Permethrin (5 gram)
0 week	1 fabric specimen	1 fabric specimen	1 fabric specimen
16th week	1 fabric specimen	1 fabric specimen	1 fabric specimen

**Table 7:** Preparation/Evaluation of Fabric Specimen for Permethrin Residue Test.

### Scope

This standard specifies the adoption of Gas Chromatography – Electron Capture Detector (GC-ECD) and Gas Chromatography – Mass Spectrometry for evaluating 6 species of pyrethroid residues in the fabric specimens mentioned in Table 7.

### Principle [20]

- Each of 6 sprayed fabric specimen with the aforesaid Recipe is cut respectively into small pieces with the size less than 5 mm x 5 mm for the steps shown below;
- Put 2 gm of the small specimen pieces into the 100 ml Erlenmeyer Flask;
- Add 50 ml Acetone-n-Hexane (1+4) into the 100 ml Erlenmeyer Flask;
- Use ultrasonic blending the solution for 20 minutes;
- Then filter the solution;
- The filtered residues is further treated with 30 ml Acetone-n-Hexane (1+4) and undergone ultrasonic blending, and then further filtered.
- All solution is gone through anhydrous sodium sulphate for hydroextraction;
- Collect and put all the solutions into 100 ml flask, then evaporate the solution under the water bath rotary evaporator at 40°C to nearly dried state; and
- Permethrin content inside the fabric specimen is evaluated by GC-ECD first and then final quantified the Permethrin residue

by GC-MS. The result of Permethrin residue in the fabric specimen as compared with the mosquito repellency efficacy shown at Table 8 as follows:

Testing Duration	Recipe A		Recipe B		Recipe C	
Concentration of Permethrin in Spray	3% Permethrin		4% Permethrin		5% Permethrin	
0 week	1 fabric specimen		1 fabric specimen		1 fabric specimen	
	RA <sub>RA</sub> (%)	Permethrin Content (g/m <sup>2</sup> )	RB <sub>RA</sub> (%)	Permethrin Content (g/m <sup>2</sup> )	RC <sub>RA</sub> (%)	Permethrin Content (g/m <sup>2</sup> )
	75.33	0.315	86.42	0.406	91.52	0.527
16th week	1 fabric specimen		1 fabric specimen		1 fabric specimen	
	RA <sub>RA</sub> (%)	Permethrin Content (g/m <sup>2</sup> )	RB <sub>RA</sub> (%)	Permethrin Content (g/m <sup>2</sup> )	RC <sub>RA</sub> (%)	Permethrin Content (g/m <sup>2</sup> )
	21.66	0.089	53.62	0.169	83.90	0.326

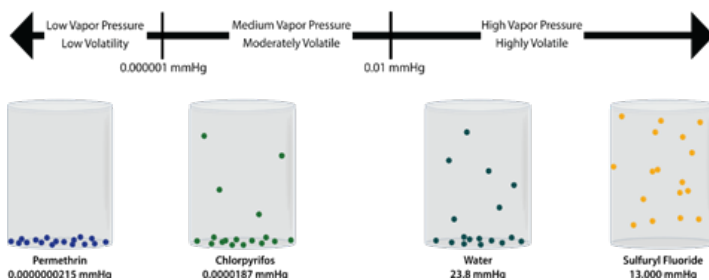
**Table 8:** The Permethrin Content inside the Fabric Specimens as compared with their Mosquito Repellency Efficacy.

## Discussion

Based on our research study and analysis, we have the following findings:

### Permethrin Vapour Pressure

Vapor pressure is a pesticide's tendency to "evaporate." In other words, to change from a solid or liquid into a vapor. In general, pesticides with low vapor pressures are less likely to turn into a vapor and get into the air.



The level of vapour pressure and volatility of Permethrin as compared with water and other chemicals is shown at Figure 2.

**Figure 2:** Pesticides and Water Vapour Pressure [21].

Many things can affect whether or not a pesticide will get into the air. In fact, pesticides can have different vapor pressures under different conditions. Temperature plays a very large role here. In general, pesticides will have lower vapor pressures at lower temperatures. As temperature goes up, so does the pesticide's vapor pressure. Other environmental factors, like climate, temperature, light and moisture level can also affect a pesticide's volatility. Light alone does not affect Permethrin content [22]. Permethrin, as compared with other pesticides and water, has a very low volatility and vapour pressure [21]. In this connection, the time taken for vaporization of Permethrin is quite longer, i.e. the Permethrin content of the fabric specimen sprayed with Recipe A (with 3%

Permethrin) has changed from 0.315 g/m<sup>2</sup> to 0.089 g/m<sup>2</sup> with the mosquito repellency efficacy decreased from 73.33% to 21.66% (Table 8). The changing duration is 16 weeks (around 4 month-time).

### Permethrin Concentration in Fabric Specimen

Referring to Table 8, more Permethrin Content of the Recipe has excellent mosquito repellency efficacy. The vaporization rate of Permethrin from the fabric specimen would be lower with minimum Permethrin content. As regard the toxicity of Permethrin to human being, the maximum Permethrin content of the fabric specimen sprayed with above-mentioned recipes is up to 5% (around 0.527 g/m<sup>2</sup>).

A reference paper [22] tells us that a study in Iranian military personnel showed that permethrin-soaked uniforms treated with 125 µg/cm<sup>2</sup> (1.25 g/m<sup>2</sup>). The Association Standard on the "Anti-mosquito Fabrics Treated with Permethrin" from China Textile Commerce Association shows that [23]:

	Non-contact Skin Textiles	Direct Contact Skin Textiles	Children's Textiles
Permethrin Content (g/m <sup>2</sup> )	< 1 g/m <sup>2</sup>	< 0.8 g/m <sup>2</sup>	< 0.4 g/m <sup>2</sup>

**Table 9:** Permethrin Content Requirements.

World Health Organization has taken a series of research and announced that as a clothing applied at 1.25 g/m<sup>2</sup> of fabric, permethrin is safe and persistent [24]. Our research team has also noticed that "Anti-mosquito Fabrics Treated with Permethrin", China Textile Commerce Association-Association Standard [23]. We then arrange the aforesaid spray recipe up to the maximum Permethrin content to around 0.5 - 0.6 g/m<sup>2</sup> regarding to the safety issue to human being. This range of Permethrin content has longer and better mosquito repellent efficacy.

## Conclusion

It is proven that the water emulsion-based Permethrin spray, as compared with aerosol-based Permethrin spray, Hansk has developed formulation with its mixture of surfactant which has enabled Permethrin small particles to penetrate into cotton fibres of knitted fabric specimen by increasing the capillary action, as well as hydrophilic property of cotton fibres. On the other hand, water emulsion-based spray eliminates the hazard risks of aerosol-based spray creating impacts to human health, environment, flammable, etc. [25].

Although Permethrin would be slowly vaporized in accordance with environmental conditions, it should have its own limitations in terms of mosquito repellent efficacy level, duration and life time. More Permethrin content has already demonstrated longer and better mosquito repellent efficacy in the aforementioned experiments, however, we should also notice the safety issue to human being due to high concentration of Permethrin in industrial application. Our next phase of research would take into account of number of washing cycles of sprayed fabric specimens with the aforesaid recipes and evaluate of the washing results regarding to

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