ISSN Print: 2394-7500
ISSN Online: 2394-5869
Impact Factor: 5.2
IJAR 2016; 2(8): 591-595
www.allresearchjournal.com
Received: 29-06-2016
Accepted: 30-07-2016

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Impact of insecticides on physical properties of mosquito bednets

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Abstract
The purpose of this study is to apply insecticides to different types of fabrics used for production of mosquito nets, and to investigate the effect of treatment on fabric physical properties. Cotton, nylon and polyester bednets were treated with deltamethrin insecticide according to the recommended dosages. The mortality percentages of mosquitoes were evaluated using WHO cone test method in the insectry of the Blue Nile National Institute for Communicable Diseases, University of Gezira. The important physical properties of bednets were tested before and after treatment using different instruments and apparatus. The study proved that deltamethrin insecticide is more effective for nylon and polyester than for cotton bednets. The tearing strength and the tensile strength decrease, while elongation increases.
Statistical Package for Social Sciences (SPSS) was used for analysis. From the findings it can be said that treatment with insecticide affect the tensile strength of all types of bednets, tearing strength on cotton and elongation on polyester. From this study, deltamethrin insecticide is preferable to be used for nylon and polyester bednets.

Keywords: Cotton, nylon, polyester, physical properties, deltamethrin insecticide

Introduction
Malaria is one of the most killer diseases, affecting millions of people mainly in the tropics. Recently, the problem of having a substantial decline in malaria incidence has been observed all over the world [1]. However, Insecticide-treated nets (ITNs) are the most powerful malaria control tool to be developed since the advent of indoor residual spraying (IRS) and chloroquine in the 1940s, and as such they have been an important component of global and national malaria control policies since the mid-1990s [2]. However, the mosquito repellency of ITNs and IRS cannot be maintained for a long duration. In addition, both of them can lead to the pollution of the environment. In order to overcome the shortcomings of ITNs and IRS process based upon the polymer-coating technique, long-lasting insecticidal nets (LLINs) have been designed by binding the insecticide onto the fibers of bed nets or fabrics.
Pyrethroids are the most effective group of insecticides advocated for the impregnation of mosquito nets due to their rapid knock-down effects, and high insecticidal efficiency at low dosages combined with relative safety for human contact, domestic handling and their low mammalian toxicity [3]. Among them, permethrin, etofenprox, deltamethrin, cyfluthrin, λ-cyhalothrin, and α-cypermethrin are recommended by the World Health Organization [4] at substance-specific application concentrations and are widely employed for insecticidal treatment of long lasting insecticide-treated net (LLIN) [5].
Presently, there are very few studies on the effect of insecticides on the physical properties of mosquito nets. [6], studied the strength of bed nets as function of denier, knitting pattern, texturing and polymer. They found that the commercial monofilaments yarn polyethylene nets are significantly stronger than the commercial multifilaments polyester nets. [7], investigated the use of bendiocarb and alphacypermethrin as finishing solutions for the preparation of anti-mosquito PET nets. They reported that the wash-resistant performance has been improved obviously in comparison with untreated PET nets. However, the aim of this work is to investigate the effect of deltamethrin insecticide on the physical properties such as tearing and tensile strength of different types of fabrics used for production of mosquito nets.

Materials and Methods

Fabrics

- Cotton Woven Bednets (Walia), Count 36x36 Tex;
- Nylon Warp Knitted Bednets (Tull); and
- Polyester Warp Knitted Bednets.

Chemicals

The chemicals used and their functions are mentioned in the following Table (1):

Table 1: The Chemicals Used and Their Functions

Chemical	Functions
Sodium hydroxide 2.5ml/l	to eliminate waxes, greases, protein substances.
Sodium carbonate 1g/l	to increase the efficiency of scouring
Wetting agent 2g/l	to enhance the wettability of fabric
Acetic acid,	to neutralize the residual alkali (NaOH)
Deltamethrin, $C_{22}H_{19}Br_2NO_3$, 25g/liter	Insecticide

Application of Insecticide

Preparation of the Bednets

Cotton yarns linear density (expressed in Tex, which is the mass in grams per 1000 meters) was determined as the mass in grams of 1 m long yarns in accordance with ASTM D 1577-96. Five readings were taken and the average is reported.

Cotton bednets were scoured with caustic soda (36 Baume) 2.5 ml/liter, Soda ash: g/liter and Wetting agent (soap): 2g/liter by using a liquor ratio (L.R) of 40:1, at temperature of 100 °C for 60 min.

Nylon and Polyester bednets were washed in a washing machine in a detergent solution.

Net Dipping Procedure

The net dipping procedure was done in an open air or in a well-ventilated building according to the following steps:

Measurement of volume of water absorbed by the nets (L.R): The volume of water absorbed by a single net was determined and then multiplied by the number of nets to be dipped and the total required volume of water was provided in the mixing container.

Measurement of the amount of insecticide required: The area of one net was measured in m^2, and then multiplied by the target dosage in mg/m^2. The result was divided by the concentration of the insecticide in mg/ml, giving the volume required by one net, the result was multiplied by the number of nets to be dipped and then, the concentration was measured out. The measured amount of insecticide was diluted with water in the mixing container.

Dipping and drying nets: The clean and dry nets were soaked in the insecticide solutions separately for 20 minutes and wringed thoroughly in order to drip the fluid into the dipping container. The treated nets were dried evenly [8].

Testing Methods

Bioassay Test (Mortality test)

The test was carried out at the Blue Nile National Institute for Communicable Diseases, University of Gezira. Ten susceptible, non-blood fed, 2–5-days old *anopheles* mosquitoes were exposed to the three types of netting materials (25cm x 25cm) for 3 minutes, under standard WHO cones, after which they were held for 24 hours with access to sugar solutions. Mortality was measured after 30 and 60 minutes post exposure and after 24 hours. Bioassay tests were carried out at a temperature of 25±2 °C and relative humidity at 75±10% [4].

Tearing Strength Test

The tearing strength was carried out at 25±2 °C and 65±2% relative humidity (RH), in accordance to the standard test method for tearing strength of fabric by falling–pendulum type (ASTM D 1424-96), by using Elmendorf's Tearing Tester, Marubeni Corporation, Textile Machinery Dep., Tokyo, Japan. The test results were represented by the mean value of testing each on warp and weft directions.

Tensile Strength Test

The strip methods were used to test the tensile strength at 25±2 °C and 65±2% relative humidity (RH), according to the standard test method for breaking force and elongation of textile fabrics (ASTM D 5035), with a Schopper Type Textile Strength Tester, Marubeni Corporation, Textile Machinery Dep. Tokyo, Japan. The average results of five measurements was reported.

Statistical Analysis Procedure

The Statistical Package for Social Sciences (SPSS) was performed. The outcome of these tests is the acceptance or rejection of:

$$t = \frac{\bar{X}_1 - \bar{X}_2}{S_{X_1X_2} \cdot \sqrt{\frac{2}{n}}}$$

Where $$S_{X_1X_2} = \sqrt{\frac{S_{X_1}^2 + S_{X_2}^2}{2}}$$

Where $S_{X_1X_2}$ is the grand standard deviation (or pooled standard deviation), 1= group one, 2= group two. The denominator of *t* is the standard error of the difference between two means. For significant testing, the degree of freedom for this test is 2n−2 where n= number of participants in each group.

Results and Discussions

Bioassay Test (Mortality test)

The results of mosquito mortality rate (knock down) were reported in Table 2, after 30 minutes, one hour and 24 hours; the mosquito mortality is very good in both nylon and polyester after 30 minutes, but for cotton it is lower compared with others, the mosquito mortality percentage increases when the time increases until it exceeds the maximum values after 24 hours. This confirms that the insecticide used is very effective for killing mosquitoes when applied at the recommended dosages, but there are some variations in mortality rate due to the variation of the type of bednets.

Table 2: Mosquito Mortality% of Bednets Treated with Deltamethrin 2.5%

Type of fabric	No. of mosquitoes exposed	Mortality% after 30 minutes		Mortality% after 1hour		Mortality% after 24 hours	
		No.	%	No.	%	No.	%
Cotton	10	10	50	10	60	10	100
Nylon	10	10	80	10	90	10	100
Polyester	10	10	90	10	90	10	100

Tearing Strength

Tearing Strength for Weft and Course

Table 3 shows the results of tearing strength (weft& course), before and after treatment. Cotton bednet has recorded the highest value of tearing strength, where polyester has the lowest value in both directions. The highest decrease in tearing strength was observed for cotton bednet. It can be concluded that, the insecticide has a negative effect on tearing strength (weft& course), especially for cotton bednet.

Table 3: Tearing Strength (weft& course)

Material Data	Tearing strength (gm)					
	Cotton		Nylon		Polyester	
	Before treatment	After treatment	Before treatment	After treatment	Before treatment	After treatment
1	2500	2100	1100	1050	290	260
2	2700	2050	1400	1200	310	268
3	2600	2150	1138	1125	300	300
$\overline{X}$	2600	2100	1212	1125	300	276
Change (%)	19.2%		7.2%		8%	

Tearing Strength of Bednets for Warp and Wale

Table 4 shows the results of tearing strength of the three types of bednets in (warp& wale) directions. Cotton bednets has recorded the highest values, while polyester shows the lowest one. The variations occurred in tearing strength before and after treatment were shown as percentages. It is revealed that polyester bednet was the mostly affected one where the highest change percentage is (30.6 %).

Table 4: Tearing Strength for all Samples (warp& wale)

Material Data	Tearing strength (gm)					
	Cotton		Nylon		Polyester	
	Before treatment	After treatment	Before treatment	After treatment	Before treatment	After treatment
1	3150	3000	1100	1250	400	250
2	3160	3000	1400	1050	306	300
3	3140	3000	1138	950	450	250
$\overline{X}$	3150	3000	1212	1083	385	267
Change (%)	4.8%		10.6%		30.6%	

The Tensile Strength

Tensile Strength of Bednets for Weft and Course

Table 5 shows the results of tensile strength (weft& course) before and after treatment, the highest value is recorded for nylon bednet, while the lowest is for polyester. The tensile strength value decreases considerably after treatment, especially for cotton and polyester bednets, consequently the insecticide has a negative effect on fabric strength regardless of the type of bednet.

Table 5: Tensile Strength of all the samples (weft& course)

Material Data	Tensile strength (kg)					
	Cotton		Nylon		Polyester	
	Before treatment	After treatment	Before treatment	After treatment	Before treatment	After treatment
1	9	6	15	12	5	1
2	12	3	16	8	5	1
3	10	4	14	12	5	1
4	11	4	15	11	5	1
5	10	5	15	10	5	1
$\overline{X}$	10.5	4.4	15	10.67	5	1
Change %)	58.1%		28.9%		80%	

Tensile Strength of Bednets for Warp and Wale

Table 6 shows the results of tensile strength (warp& wale) of bednets, before and after treatment, the highest value of tensile strength is recorded for nylon and the lowest is for polyester bednets. The values of tensile strength decrease for all the bednets after treated with insecticides. The greater decrease in tensile strength is recorded for polyester bednet, but there is a little decrease recorded for nylon and cotton bednets.

Table 6: Tensile Strength (warp& wale)

Material Data	Tensile strength (kg)					
	Cotton		Nylon		Polyester	
	Before treatment	After treatment	Before treatment	After treatment	Before treatment	After treatment
1	15	13	19	17	6	3
2	10	10	17	18	7	2
3	11	9	18	17	5	3
4	12	11	19	17	6	3
5	12	10	17	17	6	2
$\overline{X}$	12	10.67	18	17	6	2.67
Change (%)	11.1%		5.6%		55.5%	

Results of Elongation

Elongation of Bednets for Weft and Course

Table 7 shows the results of elongation (weft& course), before and after treatment; the higher elongation is recorded for nylon bednet, and the least is for cotton.

Table 7: Elongation (weft& course)

Material Data	Elongation (mm)					
	Cotton		Nylon		Polyester	
	Before treatment	After treatment	Before treatment	After treatment	Before treatment	After treatment
1	80	120	190	200	100	120
2	80	120	186	196	110	120
3	80	120	172	200	110	110
4	80	119	193	195	105	115
5	80	120	190	190	110	118
$\overline{X}$	80	120	186	196	107	116.6
Change (%)	50%		5.4%		9%	

Elongation of Bednets for Warp and Wale

Table 8 shows the results of elongation of different bednets (warp& wale); before and after treatment, the highest value of elongation is recorded for nylon bednet, where its elongation value does not change before and after treatment. For polyester there is a decrease in the value of elongation of the bednet.

Table 8: Elongation (warp& wale)

Material Data	Elongation (mm)					
	Cotton		Nylon		Polyester	
	Before treatment	After treatment	Before treatment	After treatment	Before treatment	After treatment
1	100	90	130	120	80	80
2	70	72	120	120	80	70
3	100	75	110	120	80	70
4	90	85	120	115	80	75
5	90	73	120	125	80	70
$\overline{X}$	90	79	120	120	80	73
Change (%)	12.2%		0		8.8%	

Results of Change (%) of Different Properties of Bednets

Table 9: Percentage Change (%) of Different Properties

Property	Type of Fabric		
	Cotton	Nylon	Polyester
	Percentage change		
Tearing strength Weft & course Warp & wale	-	-	-
	-	-	-
Tensile strength Weft& course Warp & wale	-	-	-
	-	-	-
Elongation Weft & course Warp& wale	+	+	+
	-	No change	-

+: Increase, - : Decrease

Table 9 shows the percentage change (%) of different properties of bednets. It is clear that the treatment with insecticide decreased the tearing and tensile strength in both directions for the three types of bednets, while increased the elongation in the weft and course directions.

Statistical Analysis of Different Properties of Bednets

Table 10: P-Values of the Properties of Different Bednets

Property	Type of fabric	P-value calculated	Significance
Tearing strength (weft& course)	Cotton	0.01	Significant
	Nylon	0.771	Not significant
	Polyester	0.150	Not significant
Tearing strength (warp& wale)	Cotton	0.00	Significant
	Nylon	0.373	Not significant
	Polyester	0.059	Not significant
Tensile strength (weft& course)	Cotton	0.000	Significant
	Nylon	0.01	Significant
	Polyester	0.00	Significant
Tensile strength (warp& wale)	Cotton	0.230	Not significant
	Nylon	0.141	Not significant
	Polyester	0.000	Significant
Elongation (weft& course)	Cotton	0.000	Significant
	Nylon	0.901	Not significant
	Polyester	0.008	Significant
Elongation (warp& wale)	Cotton	0.132	Not significant
	Nylon	1.000	Not significant
	Polyester	0.008	Significant

Table 10 shows the results of P-values for different bednets, where for cotton bednets tearing strength was mostly affected. However, for tensile strength treatment with insecticide has a significant effect on polyester fabric. For elongation the treatment showed a significant effect for cotton and polyester bednets whereas no significant effect was observed for nylon bednets.

Conclusions

Cotton, nylon and polyester bednets were successfully treated with the deltamethrin (2.5%) insecticide in accordance with the WHO recommended dosages. The treatment of bednets with insecticide is very important as preventive manner from malaria. It was found that, the mosquito mortality percentage increases when the time increases until it exceeds the maximum values after 24 hours. This confirms that the insecticide used is very effective for killing mosquitoes when applied at the recommended dosages. However, this treatment has negative impacts in some properties and positive impacts on other properties of bednets made of different materials. Almost the tearing and tensile strength are negatively affected. The overall effect of the deltamethrin (2.5%) insecticide on the properties of different types of bednets has been shown according to the P-values calculated from T-test. From the results the effect is significant on the tensile strength in the weft and course directions for the three types of bednets and significant on the tearing strength for cotton bednets.

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