Effect of airflow, rain and time on permanence of permethrin in permethrin-impregnated military uniforms

Khoobdel M. * PhD

* Health Research Center, Baqiyatallah University of Medical Sciences, Tehran, Iran

Abstract

Aims: Various factors can affect the resistance and durability of permethrin molecules on the impregnated fabrics. The aim of this study was to evaluate the effect of environmental factors such as weathering, rinsing and aging on endurance and persistency of permethrin residues in the fibers of clothes in military uniforms.

Methods: This survey is an experimental study. In this study, common Iranian military and police uniforms’ clothes were impregnated by concentrated emulsion of permethrin insecticide, at 125µg/cm² using a dipping method. Then, the influence of environmental factors such as weathering, rinsing, and aging on the persistency of impregnated clothes were analyzed. The amount of permethrin residue was determined by High Performance Thin Layer Chromatography (HPTLC) technique.

Results: Without considering the uniforms, on average, 89.7±2µg/cm² of the permethrin equivalent to 71.7% remained after 12 weeks of permanent, day and night weathering. After rinsing of impregnated uniforms with permethrin for 12.5 hour in water, only 93.5±2.7µg/cm² of permethrin, equivalent to 75%, remained in fabrics. Keeping the impregnated clothes for 6 months away from the influence of environmental factors in darkness, and laboratory condition in package form, did not significantly reduces the amount of permethrin.

Conclusion: The environmental agents such as wind and weathering, raining and chemical reactions which happen gradually and with the passage of time, all have a moderate and little effect and cannot considerably affect the reduction of the efficiency of impregnated uniforms.

Keywords: Impregnation, Permethrin, Military Uniforms, Weathering, Rain, Aging

Introduction

Insects and some arthropods such as ticks are vectors of many diseases. Iran, like many Eastern Mediterranean countries, is the most important focal point of insect borne diseases in the world [1]. Insect borne diseases have been identified as the military force diseases and as soldier disabling agents [2]. Military forces, due to high exposure to these creatures in most part of the world are considered as the group prone to arthropods transmitted diseases [3, 4]. Military career is basically associated with a high risk of arthropods transmitted diseases. Diseases such as malaria, leishmaniasis, dengue fever, and Lyme, depending on different geographical regions have more threats for militaries than usual people [5, 6]. During the imposed war, in the west and south war zones, Iranian soldiers and fighters intensively faced some arthropods born diseases like leishmaniasis, three-day fever, scabies and scorpion bites [7].

Permethrin impregnation of military uniforms is considered as the effective and safe way of individual protection for military forces [8, 9]. Its risk analysis in recent years in Germany military forces has shown the safe use of permethrin-impregnated military uniforms by allowed dosage for soldiers [10]. Several researches in different parts of the world have been done on the evaluation of permethrin-impregnated military uniforms, and the efficacy of this method against insects and biting arthropods has been proven [11, 12]. At the present time, the United States, Germany and England soldiers who are in Iraq and Afghanistan use permethrin-impregnated military uniforms widely [2, 13].

Regarding the efficiency of this technique in other armies of the world, use of this method for Iranians has been recommended in recent years [14]. Studies in Iran have shown that permethrin impregnated military uniforms create considerable (about 70-90%) protection against the bites of mosquitoes such as Culex and Anopheles stephensi (the main vector of malaria in the south part of Iran) in normal situations [15, 16]. Equipping soldiers with impregnated uniform technique is considered as a non-operating protection, yet in Iran it has not been considered and used by military forces and has not been placed in soldiers’ personal protection equipment list [17]. Various factors can affect the maintenance and durability of permethrin fiber uniforms some of which have been studied in the United States and some European countries [18, 13, 19, 20]. Durability or permanence rate of permethrin in permethrin-impregnated clothing against different methods of...
washing has already been studied [21]. The aim of the present study was to investigate the effect of such environmental factors as wind, dipping, and time on the amount of permethrin left over different soldier clothing fabrics.

Methods

This experimental and controlled interventional study was conducted in 2004-5, during May, June and July (due to synchronization with the seasons of insects activity and high exposures of humans to insects) on six types of common uniforms in military and police forces of Iran in the area of Tehran and pesticide chemistry laboratory of Tehran Medical University.

Physical characteristics of selected textile fibers such as material, weight, thickness and some other physical properties was determined in the textile fabric faculty of Amirkabir University (due to issues, the name and using location of the uniforms and their precise characteristics was not revealed and U1–U6 have been used for naming the six kinds of the studied uniforms).

Impregnation: To determine the coefficient index of water absorption for each type of cloth, previous studies were used [21]. To impregnate each of the uniforms, solutions with the certain concentration of undiluted emulsion of permethrin 10% with the molecular formula trans/cis isomer by the ratio of 25%/75% were prepared (Bayer, Prigen; Germany). Concentration of permethrin-impregnating solutions was determined in proportion of six uniforms clothes’ absorption coefficient and then impregnation was performed using a dipping method [22, 23], so that the desired dose of 0.125mg/cm² was absorbed on the surface of the fabric approximately uniformly. To ensure the accuracy of impregnation method, and the equal spread and distribution of insecticide in all parts of the desired textile fabric, after each impregnation and drying of the impregnated pieces and before studying the impact of the given environmental factors, some pieces (3-4 cases) of each fabric were selected randomly. Then 2 cm³ of samples were prepared from their middle parts and sides and the permethrin content was extracted. For cost saving of insecticides, improving the accuracy and ease of work and consistency with most experimental studies, 12x15cm pieces of each fabric were prepared and used in impregnation and study of the environmental factors. Impregnated pieces were placed in laboratory environment for 24 hours (away from direct sunlight and at 23-26°C and relative humidity of 30-40%) to be completely dried, and then they were encoded. Then, they were placed in plastic bags and were used in the laboratory test.

Effect of weathering: Nine pieces of six impregnated fabrics and one non-impregnated piece of each were selected as controls and were placed for three months in front of the airflow based on Schreck’s et al. method [24]. A closed environment was selected, which was away from sunlight effect, rain and wind and the prepared pieces were hanged suspended in the air from a rope by clamp. Although permethrin is one of the resistant pyrethroid insecticides against sunlight and heat, to avoid any possible destructive effect of direct sunlight impregnated pieces were hanged in an environment protected by shelter. Each week a six series (one piece of each fabric) from impregnated pieces accompanied with control sample from hung pieces were selected. Some 2 cm² samples were isolated from each impregnated piece and were placed in the vial and transferred to a laboratory for determination of the residual amount of permethrin. To avoid the reduction of insecticide in each piece that may happen due to abrasion and other factors, tested pieces were not reused and just the control sample was transferred to the environment with shelter. This survey continued for twelve weeks until finishing of all hanged pieces. During the test, the average temperature, the maximum, minimum and the relative humidity were recorded during the day and night.

Effect of dipping in water: The effect of heavy or prolonged rain on permethrin-impregnated uniforms was determined by floating in tap water. Dipping test was done based on Schrek’s et al method as follows [25]:

1. Ten impregnated pieces of six types of fabrics, and a total of sixty pieces were selected.
2. 8 liters of tap water (22-26°C) was poured in ten-liter pans. Each pan was allocated to one type of fabric and ten pieces of each type of fabric were soaked in it.
3. Every 15 minutes the water in pans was changed and samples were rinsed in fresh water (pieces were carefully watched to not stick together). One fifteen minute period was regarded as an order of dipping.
4. Every 75 minutes (after five dipping orders), one series of pieces (one type of each fabric) was brought out from water and dried outdoor (finally 48 times of rinsing were done in 12 and a half hours maximally).
5. All the above steps were identically done for the non-impregnated control samples as well.

Effect of time: In this test, 12 permethrin-impregnated pieces of each type of fabric, a total 72 pieces, and the same number of control samples (impregnated by water and solvent) were selected. Pieces were encoded, packaged separately in plastic bags, and kept
in a dark place at the room temperature (24-26°C). Control samples were kept apart from the impregnated ones. At the end of each month, one series of the control clothes (one type of each six fabric) and one item of packaged samples were transferred to laboratory for analysis of the residual amount of permethrin. This study was done during 12 months.

Advanced thin-layer chromatography: Advanced thin-layer chromatography with a powerful scanner can quantitatively recognize the material exactly and even separate and determine the isomers at the nanogram level [26]. To determine the residual amount of permethrin on clothing, after each time of exposure, 2 cm² pieces of impregnated uniforms were isolated and kept in the refrigerator at a temperature of 8°C to determine the amount of permethrin in the surface. To extract permethrin, 1 ml of pure acetone was added to each vial containing 2 cm² pieces, then the lids were covered and for 10 minutes and were treated with a shaker device at an average speed. Then vials were in a laboratory for 60 minutes. Using the capillary tube (5 μl) and blot apparatus, blotting was done on the aluminum plate containing silica gel (Merck, 60F 254nm, Germany). 10 micro liter volumes of each spot and 1 cm distance of the patches was selected. To blot the standard sample "multiple levels" method and 10 mg (AccuStandard, Switzerland) as the standard amount for permethrin was used. To blot in this method, several concentrations or volumes of a standard concentration is used. Finishing the blotting steps and when the spots dried, the plate was placed in a solvent tank. The solvent or mobile phase composition used for permethrin N-hexane/ Ethyl's acetate was in a ratio of 5%/95% which after saturating the space of a tank (about 30 minutes) the acetate was in a ratio of 5%/95% which after extracting permethrin, 1 ml of pure acetone was added to determine the amount of permethrin in the surface. To determine the amount of permethrin in the surface. To determine the amount of permethrin in the surface.

The fabrics of the six types of evaluated uniforms were different in terms of maintaining the levels of permethrin over time and in this respect there was significant difference between the uniforms in this regard (p<0.05). On average and regardless of the type of uniforms, after six months of ongoing maintenance, 115.5±2.7 μg/cm² (approximately 92%) of permethrin were left on the fibers that had not any significant difference with the initial rate of permethrin (p>0.05). After 12 months of storage, 97.7±2.9 μg/cm² (approximately 78%) of permethrin was detected (Table 1).

Averagely and regardless of the type of uniform, after 12.5 hours of soaking of permethrin-impregnated uniforms in water, 93.5±2.7 μg/cm² (approximately 75%) of the amount of permethrin remained on the fibers. Soaking in water had different effects on the nonparametric Kruskal-Wallis test like stability of variance and normality of data was used. To understand the time of significant deduction of permethrin affected by such factors as airflow, rising and aging, Dunnett’s qualitative test was applied. To analyze the data SPSS 12 software was used.

### Results

At the period of studying the airflow, the average day and night temperatures were measured respectively to be 32°C (ranging from 22-40°C) and 25°C (ranging from 16-28°C) and the mean relative humidity was measured as 38±11%. During the study of time factor, the average temperature in the keeping place of clothes was recorded to be 24.5°C (ranging from 22/25-27°C) and relative humidity as 32% (ranging from 28-48%).

### Table 1 - The amount of permethrin left in the impregnated uniforms within a year separated by month (μg/cm²)

<table>
<thead>
<tr>
<th>Uniform</th>
<th>Month</th>
<th>U1</th>
<th>U2</th>
<th>U3</th>
<th>U4</th>
<th>U5</th>
<th>U6</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>124±2.2</td>
<td>124±1.9</td>
<td>125±1.8</td>
<td>124±1.4</td>
<td>125±1.6</td>
<td>125±1.9</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>123±3.7</td>
<td>127±3.7</td>
<td>124±1.9</td>
<td>124±1.4</td>
<td>126±5.8</td>
<td>124±2.6</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>125±1.3</td>
<td>119±0.6</td>
<td>123±2.7</td>
<td>126±0.9</td>
<td>123±4.8</td>
<td>126±3.2</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>124±2.2</td>
<td>134±3.4</td>
<td>121±1.1</td>
<td>124±1.0</td>
<td>122±4.1</td>
<td>128±3.0</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>128±3.9</td>
<td>136±3.7</td>
<td>121±1.6</td>
<td>127±1.6</td>
<td>121±4.8</td>
<td>125±3.7</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>131±1.1</td>
<td>124±7.4</td>
<td>109±1.8</td>
<td>126±2.8</td>
<td>122±3.0</td>
<td>126±1.2</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>119±4.9</td>
<td>117±4.0</td>
<td>85±2.3</td>
<td>126±2.5</td>
<td>123±4.5</td>
<td>125±2.2</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>130±1.3</td>
<td>107±1.5</td>
<td>63±1.4</td>
<td>125±2.4</td>
<td>122±1.9</td>
<td>116±3.8</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>110±2.5</td>
<td>110±0.9</td>
<td>68±1.3</td>
<td>117±2.8</td>
<td>117±3.0</td>
<td>112±3.5</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>105±2.6</td>
<td>105±1.9</td>
<td>63±1.7</td>
<td>118±2.4</td>
<td>119±5.1</td>
<td>104±2.9</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>102±3.2</td>
<td>99±2.9</td>
<td>62±1.6</td>
<td>116±3.4</td>
<td>116±4.1</td>
<td>91±2.0</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>90±4.2</td>
<td>102±1.6</td>
<td>56±1.9</td>
<td>115±3.8</td>
<td>115±4.2</td>
<td>82±2.1</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>91±4.9</td>
<td>90±1.0</td>
<td>48±3.0</td>
<td>96±1.6</td>
<td>100±3.2</td>
<td>76±2.7</td>
<td></td>
</tr>
</tbody>
</table>

The significant decrease of permethrin is started from the gray blocks in comparison with its initial value (p<0.05).

Khoobdel M.
Effect of airflow, rain and time on permanence of permethrin in permethrin-impregnated military uniforms

permethrin residues in different uniforms and this difference was significant (p<0.05; Table 2).

Table 2 - The amount of permethrin left in the impregnated uniforms under the influence of dipping in water (µg/cm²)

<table>
<thead>
<tr>
<th>Uniforms</th>
<th>U1</th>
<th>U2</th>
<th>U3</th>
<th>U4</th>
<th>U5</th>
<th>U6</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>126±2.6</td>
<td>125±3.1</td>
<td>126±2.3</td>
<td>127±2.1</td>
<td>126±3.0</td>
<td>128±0.9</td>
</tr>
<tr>
<td>1</td>
<td>124±2.6</td>
<td>107±3.3</td>
<td>106±1.0</td>
<td>124±4.2</td>
<td>125±2.6</td>
<td>126±2.1</td>
</tr>
<tr>
<td>5</td>
<td>125±2.7</td>
<td>110±1.1</td>
<td>101±1.0</td>
<td>129±6.1</td>
<td>125±2.6</td>
<td>127±2.3</td>
</tr>
<tr>
<td>10</td>
<td>120±2.9</td>
<td>113±2.8</td>
<td>102±2.1</td>
<td>129±4.9</td>
<td>125±1.8</td>
<td>125±1.6</td>
</tr>
<tr>
<td>15</td>
<td>121±2.5</td>
<td>109±2.5</td>
<td>93±1.4</td>
<td>126±7.1</td>
<td>124±6.1</td>
<td>125±1.4</td>
</tr>
<tr>
<td>20</td>
<td>122±1.4</td>
<td>101±1.2</td>
<td>89±1.1</td>
<td>127±5.6</td>
<td>124±2.1</td>
<td>126±3.1</td>
</tr>
<tr>
<td>25</td>
<td>121±4.0</td>
<td>91±0.9</td>
<td>89±1.2</td>
<td>125±4.1</td>
<td>122±2.5</td>
<td>128±4.4</td>
</tr>
<tr>
<td>30</td>
<td>118±3.8</td>
<td>87±0.4</td>
<td>90±2.7</td>
<td>116±1.7</td>
<td>113±3.5</td>
<td>106±4.6</td>
</tr>
<tr>
<td>35</td>
<td>106±2.1</td>
<td>87±1.6</td>
<td>82±1.9</td>
<td>112±3.8</td>
<td>123±2.1</td>
<td>106±5.6</td>
</tr>
<tr>
<td>40</td>
<td>107±2.6</td>
<td>87±1.8</td>
<td>84±0.7</td>
<td>115±6.0</td>
<td>112±6.4</td>
<td>108±5.8</td>
</tr>
<tr>
<td>50</td>
<td>87±2.3</td>
<td>80±1.7</td>
<td>77±1.6</td>
<td>105±3.8</td>
<td>120±3.7</td>
<td>92±2.9</td>
</tr>
</tbody>
</table>

The significant decrease of permethrin is started from the gray blocks in comparison with its initial value (p<0.05).

After 12 weeks of continuous and 24-hour keeping of cloth impregnated with permethrin exposed to airflow and time, averagely (regardless of uniforms' type) 89.7±2µg/cm² (71.7%) of the amount of permethrin was left on the fibers. The percentage of permethrin reduction in fibers of uniforms in the first week after dipping was not significant (p>0.05). Reduction of residual permethrin in the impregnated uniforms in the second week was significantly more than the next weeks (p<0.05), so that the average permethrin reduction in six uniforms in the second week was 14.6% and the average permethrin reduction in permethrin in the next weeks was about 2.5%, respectively (Table 3). In terms of the effect of airflow (three months), there was no significant difference between five types of uniforms U1, U2, U4, U5 and U6 (p>0.05) and only uniforms U3 showed significant difference compared to uniforms U4, U5 and U6 (p<0.05).

Table 3 - The percentage of reduction in permethrin in impregnated uniforms exposed to airflow during 12 consecutive weeks

<table>
<thead>
<tr>
<th>Course Uniforms</th>
<th>The First Week</th>
<th>The Second Week</th>
<th>3-12 Week</th>
</tr>
</thead>
<tbody>
<tr>
<td>U1</td>
<td>2.3</td>
<td>12.9</td>
<td>2.7</td>
</tr>
<tr>
<td>U2</td>
<td>0</td>
<td>17.2</td>
<td>2.9</td>
</tr>
<tr>
<td>U3</td>
<td>0.8</td>
<td>19</td>
<td>3.1</td>
</tr>
<tr>
<td>U4</td>
<td>0</td>
<td>13</td>
<td>2.2</td>
</tr>
<tr>
<td>U5</td>
<td>1.5</td>
<td>18</td>
<td>1.6</td>
</tr>
<tr>
<td>U6</td>
<td>4.7</td>
<td>7.3</td>
<td>2.6</td>
</tr>
</tbody>
</table>

The mean percentage of reduction per week 1.5 14.6 2.5

Discussion

According to the results obtained from this study, keeping the impregnated uniforms for six months in laboratory condition in darkness in packages, far from environmental factors did not create any significant reduction in permethrin and after this period, regardless of the type of uniform, about 92% of the initial permethrin remained. Furthermore, after 12 months maintenance of 977±29g/cm² (approximately 78%) of permethrin leftover was recognizable. In a similar study in the United States, soldiers' uniforms, it was shown that if impregnated uniforms are kept in black bags in darkness and at the room temperature, for at least 4-6 months after impregnating its effect will be preserved without any significant change in comparison with the first day [28].

Furthermore, in other studies, it was shown that factors as sunlight and aging have the minimum effect on permethrin-impregnated clothes, but washing the uniforms is an effective factor in decreasing the amount of permethrin of the fibers [19, 22, 29]. Sometimes there may be need to maintain the impregnated uniforms in stores for a long time; therefore, dipping method cannot be completely effective. Using polymer permethrin formulation, can solve the defects resulted from the effect of environmental factors and other permethrin reduction factors and resist against wearing and washing for 100 times [13].

The field study that was done on the United States soldiers in Afghanistan shows that wearing the polymer formulated impregnated uniforms in military operations for a long time, repeated washing and storing won't have any effect on the insecticide property of the uniforms and this effect will remain forever [18].

Regardless of type, dipping the permethrin-impregnated uniforms for 12/5 hours creates a significant but little reduction in permethrin and approximately 75% of permethrin remained on the fabrics. In another similar study, impregnating of uniforms in tap water for 12/5 hours has not created any significant reduction in permethrin and in the power of insecticide against Aedes aegypti (yellow-fever vector); therefore, this can represent the resistance of impregnated uniforms against water flow [25]. According to these results, it can be stated that permethrin-impregnated uniforms can be very resistant against washing (without detergent) and rain, so they undoubtedly can be used in rainy regions.
After 12 weeks in which impregnated clothes were placed continuously in airflow, regardless of the type of uniform, approximately 72% of permethrin resided on the fabrics. Placing the impregnated uniforms in airflow, has a mild effect on the reduction of permethrin in uniforms as in this study, after being placed in airflow continuously for three months (during 24 hours), about 28% of the permethrin of the impregnated uniforms reduced.

Generally, studied environmental factors in all six types of uniforms caused a rather mild reduction on the amount of permethrin. In terms of speed track and reduction rate of permethrin, some of the uniforms had significant differences from others. For example, under the influence of environmental factors in most of the cases, uniform U3 had a significant difference with other uniforms and the reduction rate of permethrin in each assigned time, under the effect of environmental factors, was more than the other ones. This issue is related to the material and other characteristics of clothes' fabrics.

Surveys have shown that some fabrics and different cloth materials such as cotton, hemp, wool, nylon, and polyester will represent different results in terms of the permanence effect of permethrin and insecticide property after being impregnated [30]. For example, performed surveys show that pure fabrics of wool and cotton preserve their insecticide property until one year after being impregnated, but pure fabrics of polyester or polyamide will lose their insecticide property much sooner [31]. Regarding the fact that each type of fabric has its own physical properties, there can be seen some differences in the penetration and substitution of insecticide molecules in the pores of webs and physical connection with them.

It should be considered that the material and composition of the impregnated fibers are of the most important indexes and properties in preserving insecticides. Regarding the material of uniforms, U3 had more percentages of polyester fibers than the other types; therefore, at the time of impregnation this issue can be effective in penetration and absorption of permethrin in fibers and inner or outer layers, the resistance, and durability of it inside the fibers during the effect of environmental factors, as well. On the other hand, it is proven that in nylon and polyester fibers, more percentages of insecticide are replaced on the outer layer of fibers [31]. So in impregnated uniform U3, permethrin molecules would be placed on the outer layers of fibers, which results in more touch of insecticide; this index is greatly for polyester and nylon fibers than other materials. Consequently, insects will be exposed to a higher level of insecticide and finally the percentage of insects' mortality will increase during the bioassay test. On the other hand, performed researches show that pure wool or cotton fibers preserve their insecticide properties until one year after being impregnated; whereas, pure polyester or polyamide fibers will lose the insecticide properties much sooner [30, 31]. Generally, environmental factors have mild and small effects on the amount of permethrin; whereas, such factors as washing has a great and intense effect on the reduction of permethrin from the impregnated fibers [21]. Given that, studies have proven that impregnating uniforms with polymer permethrin formulation is more effective than rinsing formulation and that resistance and durability of permethrin will increase under the influence of physical and environmental factors and consequently, the effects will increase [13, 18]. The results of this study show that the effect of environmental factors will result in decreasing the residual amount of permethrin in impregnated clothes. So it is suggested to perform studies on impregnation of uniforms with polymer permethrin formulation.

**Conclusion**

Such environmental factors as wind, airflow, chemical interactions which happen gradually due to time passing are all effective in resistance and permanence of permethrin. The influence rate of the factors is different and related to the material of the cloth fibers. Regardless the type of uniforms, these impregnated clothes can be preserved in stores for six months after being rinsed, without any significant decrease in permethrin.

**Acknowledgement:** This project was performed with the financial support of health faculty and health research institution of Tehran Medical University. The textile fabric engineering faculty of Amirkabir University is greatly appreciated due to faithful cooperation in the field of analysis of fibers of clothes and presenting information and scientific sources. Dr. Mohammad Reza Akhond from Tarbiat-Modarres University is sincerely appreciated because of his statistical consultation.

**References**

Effect of airflow, rain and time on permanence of permethrin in permethrin-impregnated military uniforms