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CHARACTERIZATION OF AIRBORNE PERMETHRIN DURING THE MANUFACTURE OF ARMY COMBAT UNIFORMS USING PRE-TREATED FABRIC

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PREFACE

This report describes efforts by the U.S. Army Natick Soldier Research, Development and Engineering Center (NSRDEC) to characterize the airborne concentration of permethrin within cut and sew facilities when manufacturing military uniforms from permethrin-treated fabric in order to determine if there is an inhalation exposure risk to garment workers. The work was funded by the US Army Research, Development and Engineering Command, Army Manufacturing Technology (ManTech) Program under Project M. NSC.2012.01. the work was performed during the period July 2013 to July 2015. The multi-disciplined team included the NSRDEC Textile Materials Evaluation Team and Industrial Hygienists from the Uniformed Services University for Health Sciences, who were funded under Grant # HU0001-14-1-007. NSRDEC contracted with UNICOR to have the uniforms cut and sewn, under Contract # W911QY-14-F-0148.

EXECUTIVE SUMMARY

Introduction

Between July 2013 and July 2015, the U.S. Army Natick Soldier Research, Development and Engineering Center (NSRDEC) evaluated the inhalation risk of cutting and sewing fabrics that have been pre-treated with permethrin, which is the only insecticide registered by the US Environmental Protection Agency (EPA) to treat clothing and uniforms. The current permethrin application method used by the US Military is an end-item treatment. Such treatments require that uniforms be manufactured prior to treatment, which leads to the risk of failures of full lots of finished uniforms. Thousands of garments must be destroyed for testing in order to ensure that the permethrin treatment meets the appropriate dosage level and EPA requirements. Failures result in unusable items that must be destroyed. Pre-treating fabric with permethrin is a viable option to reduce lead time and the risk of failing lots of uniforms. It also eliminates the need to destroy finished garments for testing.

Because the inhalation risk of manufacturing uniforms from pre-treated fabrics is not fully known, the Army assessed the concentrations of airborne permethrin during the cutting and sewing operations used to manufacture uniforms.

Methods

The sole objective of this project was to quantify the airborne concentration of permethrin within cut and sew facilities when manufacturing military uniforms from permethrin-treated fabric. This was accomplished by conducting air sampling at three cut/sew facilities during the manufacture of uniforms with permethrin-treated fabric: Integrated Textile Solutions (ITS), Inc., Roanoke, VA (cutting); UNICOR, Beaumont, TX (sewing trousers); and UNICOR, Seagoville, TX (sewing coats). The results obtained were compared to the US Department of Labor Occupational Safety and Health Administration (OSHA) Permissible Exposure Limit (PEL) for pyrethrum, which contains similar compounds, to determine if there is an inhalation exposure risk to garment workers performing the necessary operations to manufacture a uniform using permethrin-treated fabric, as there is no PEL specific to permethrin.

Results

Baseline sampling at all three facilities using untreated material showed no results above the detection limit. Pilot sampling showed two samples above the detection limit at the ITS facility and only one sample above the detection limit at the Beaumont facility, but 33 pilot samples were above the detection limit at the Seagoville facility. Data at the ITS and Beaumont facility were so highly censored that statistical analysis was not possible to estimate an upper tolerance limit. At the Seagoville facility there were enough samples above the detection limit for upper tolerance limits to be determined for three of the exposure groups: Quality Assurance (QA), Sewing, and Heat Sealing. Upper tolerance limits for these groups were $18\mu\text{g}/\text{m}^3$, $6.8\mu\text{g}/\text{m}^3$, and $8.9\mu\text{g}/\text{m}^3$, respectively. Comparison of the most conservative ($18\mu\text{g}/\text{m}^3$) of these limits to the PEL for the similar compound pyrethrum promulgated by OSHA (an 8-h time-weighted average of $5000\mu\text{g}/\text{m}$) indicates that with 95% confidence, 95% of the highest exposures to

permethrin were 278 times lower than the PEL (or 0.4% of the PEL) for the similar compounds found in pyrethrum.

Conclusions

The most conservative estimate of the airborne concentration of permethrin in these facilities is suggestive of levels safely below occupational exposure concern. However, since this is based on a PEL not specific to permethrin, it is recommended that industry incorporate local standard operating practices to monitor permethrin levels and facility air changes.

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CHARACTERIZATION OF AIRBORNE PERMETHRIN DURING THE MANUFACTURE OF ARMY COMBAT UNIFORMS USING PRE-TREATED FABRIC

1. INTRODUCTION

This report describes a 2-year study completed by U.S. Army Natick Soldier Research, Development and Engineering Center (NSRDEC) in July 2015 to evaluate the inhalation risk of cutting and sewing fabrics that have been pre-treated with the pesticide permethrin. The sole objective of this project was to quantify the airborne concentration of permethrin within cut and sew facilities when manufacturing military uniforms from permethrin-treated fabric. This was accomplished by conducting air sampling at each cut and sew facility during the manufacture of uniforms with permethrin treated fabric and comparing them to the US Department of Labor Occupational Safety and Health Administration (OSHA) Permissible Exposure Limit (PEL) for pyrethrum to determine if there is an inhalation exposure risk to garment workers performing the necessary operations to manufacture a uniform using permethrin-treated fabric.

Permethrin [(3-phenoxyphenyl) methyl 3-(2, 2-dichloroethenyl)-2, 2-dimethylcyclopropane carboxylate] belongs to the pyrethroid class of insecticides and was first registered in 1979. Registrations include both agricultural and non-agricultural uses.¹ Pyrethroids are synthetic chemicals that act like the natural extract pyrethrins.² Pyrethrins are a mixture of chemicals found naturally in the extracts (pyrethrum) of some chrysanthemum flowers. Pyrethrums are a mixture of molecules that are toxic to insects.³ Permethrin is chemically and toxicologically very similar to these naturally occurring pyrethrin compounds. More than 20 synthetic pyrethroids exist, and the primary purpose behind the chemical modifications used to produce pyrethroids is to render them less susceptible to degradation in sunlight.⁴ At the low level of treatment used for clothing, permethrin acts as an effective repellent for insects. Currently, there are many applications of permethrin on fabrics to include commercial clothing, military uniforms, bed nets, and relief blankets. All permethrin use is regulated by the US Environmental Protection Agency (EPA)⁵ and therefore must be controlled to meet the standards set forth in the registrations. This includes manufacturing processes and end-items. At this time permethrin is the only pesticide registered to treat fabrics.⁵

The current permethrin application method used by the US Military is an end-item process: the uniforms are manufactured prior to being treated. To ensure that the permethrin treatment meets EPA requirements, the garments must be destroyed for testing. As a result, thousands of treated garments are rendered useless each year. An alternative treatment application process is an open-width fabric-pad application, a widely used commercial method of applying functional finishes to fabrics during textile processing. Unlike end-item treatment, the fabric can be tested without destruction of the garment to ensure the appropriate treatment levels, efficacy, and durability are met prior to the mass production of uniforms.

In 1994, the National Research Council (NRC) reported findings from an independent evaluation performed by its Committee on Toxicology, Subcommittee to Review Permethrin Toxicity from Military Uniforms Subcommittee, of the safety of wearing uniforms and for personnel working with permethrin pre-treated fabrics. Based on its review of the toxicity data from the evaluation,

the Subcommittee concluded that Soldiers who wear permethrin-impregnated Battle Dress Uniforms (BDUs) are unlikely to experience adverse health effects and that the risk to garment workers who handle permethrin-impregnated fabric is even smaller. The Subcommittee considered the dermal route to be the only relevant route of exposure to permethrin from wearing permethrin-treated BDUs or working with treated fabric. It also stated, however, that depending on the degree of ventilation and dust removal in the cutting and sewing processes and the type of protective clothing and equipment worn by garment workers, airborne particles could constitute an additional source of exposure to permethrin.⁶ In 2009, the US EPA Registration Eligibility Decision for Permethrin similarly concluded that exposure to military personnel from wearing permethrin-treated uniforms and to garment workers involved in manufacturing of clothing pre-treated with permethrin was not found to exceed the agency level of concern.¹ The US EPA assessment, however, similarly did not include an assessment of permethrin from the inhalation route of exposure.

Based on the NRC Subcommittee finding that airborne particles could constitute a source of exposure to permethrin not explored in its evaluation, the Army decided to evaluate the health risk of cutting and sewing permethrin-treated fabrics by quantifying the airborne exposure to permethrin at contractor facilities during the cutting and sewing operations for the production of Army uniforms. To support this effort, the Uniformed Services University of the Health Sciences (USUHS) agreed to conduct air sampling to quantify the airborne concentration of permethrin during various work tasks performed within cutting and sewing facilities while manufacturing military uniforms using fabric that was pre-treated with permethrin. .

2. SAMPLING APPROACH

Untreated 50:50 nylon: cotton ripstop fabric was used in baseline sampling. The same type of fabric was then treated with permethrin and used in pilot sampling.

2.1 PERMETHRIN TREATMENT

Permethrin treatment of the fabric was carried out by Carlisle Finishing in Carlisle, South Carolina under International Textile Group's EPA Registered Product, No Fly Zone (EPA Registration Number: 83588-1). Random samples from four production lots were cut and sent to NSRDEC for permethrin content verification prior to cutting and sewing the treated fabrics. Verification testing was completed to ensure compliance with EPA registered permethrin levels and appropriate dose rates on the 50:50 Nylon: Cotton Fabric.

2.2 SAMPLING LOCATIONS (MANUFACTURING FACILITIES)

The three facilities were used in the study:

- Cutting: Integrated Textile Solutions (ITS), Inc., Roanoke, VA
- Sewing, trousers: UNICOR (Beaumont Facility), Beaumont, TX
- Sewing, coats: UNICOR (Seagoville Facility), Seagoville, TX

Three visits were made to each of the three locations. The first visit was to observe the work processes in order to develop a sampling plan based on presumptive similar exposures based on observed work tasks and operations. The second visit was to conduct air quality sampling during the manufacture of uniforms with untreated fabrics in order to establish a baseline. The third and final visit was to conduct air quality sampling during the manufacture of uniforms using the permethrin-treated fabrics (pilot study).

2.3 EXPOSURE GROUPS

The observed work processes during the first visit were used to determine similar exposure groups (SEGs). These were established based on similar observed work tasks and operations at each facility. The SEGs at ITS were:

- Spreader
- Cutting/sorting
- Quality assurance (QA)/supervisor
- Binding/boxing
- Slit goods

The ITS cutting/sorting personnel cut uniform components from the fabric sheets and sorted them for binding and boxing. Binding/boxing personnel manually manipulated stacks of uniform components after binding them for shipment. Slit goods personnel cut the rolls of fabric into smaller pieces and created visibly higher amounts of dust. Supervisors in the ITS facility both performed QA duties and handled the more administrative tasks.

The components prepared at ITS were then shipped to the two UNICOR sewing facilities to be assembled into completed uniforms. The SEGs at the two UNICOR facilities were:

Beaumont:	Seagoville:
• Sorting	• Sorting
• Sewing	• Sewing
• QA	• QA
• Supervisor	• Supervisor
• Warehouse	• Warehouse
• Mechanic	• Mechanic
• Marker	• Marker
• Leadman	• Leadman
• Steamer	• Heat Sealer
• Vacuumer	• Vacuumer
• Orderly	• Orderly

At the sewing facilities, sorting and receiving workers manually handled and moved bundles of fabrics about the facility. All sewing operations involved handling the material, resulting in visible fabric dust buildup during the sewing process; workers at the sewing operations were generally stationary within the facility. QA personnel manually handled fabrics and inspected the quality of work. Supervisors at the UNICOR facilities were correctional officers and generally did not handle or manipulate uniform fabrics in any way. Warehouse personnel and mechanics did not typically handle the material, but had the potential to be incidentally exposed. Markers handled the material to prepare it for further cut and sew operations. The Leadman was a floor supervisor and handled material and assisted in various production activities as needed. Steamers applied steam to the fabric to prepare the material for further production activity requiring smooth surfaces. Heat sealers used a high heat machine to fuse fabric pieces to backing/interlining materials. Vacuumers used vacuum sheers to clean up threads from the manufactured uniforms. Orderlies moved about the facility and kept the floors and areas clean throughout the day.

2.4 SAMPLING PROCEDURES

The same sampling procedures were followed for both the baseline and pilot studies. All air quality samples were collected as personal samples from volunteers or from area monitoring, which was carried out by dividing each facility into quadrants. The area samples were collected at the approximate midpoint of each quadrant. Samples were collected using an OSHA Versatile Sampler (OVS) with XAD-2 collection sorbent and glass fiber filter (SKC® Inc., Eighty Four, PA; Catalog No. 226-30-16) with SKC® 224-44XR (SKC® Inc., Eighty Four, PA) sampling pumps operated at a nominal flow rate of 1 L/min for the full shift of each worker. Sampling media and sampling flow rate were selected based upon guidance for the collection of pyrethrum in the OSHA 70 method, with the exception that the sample time was extended from 1 h up to the full shift of the worker (typically 6-9 h). This modification was done to increase the permethrin mass collected on the media, as concentrations were anticipated to be very low and would otherwise not be capable of detection by the analytical technique. Samples were stored on site until the end of each trip (approximately 3 days to 1 week). For field sampling quality control, two field blanks for each day of sampling were included for analysis.

3. EVALUATION METHODS

3.1 PERMETHRIN VERIFICATION

Permethrin content was verified by the Textile Materials Evaluation Team (TMET) at NSRDEC. Permethrin verification was completed as specified in GL/PD 07-13 and 07-14. The verification test method can be found in Appendix A. Four lots were tested.

3.2 FACILITY VENTILATION TESTING

The ventilation at each facility was assessed for the number of air changes per hour using a TSI VelociCalc® 9545-A thermal anemometer. Air change calculations were based on total exhaust air flow out of the facility by measuring air flow from the general dilution exhaust terminals.

3.3 BASELINE SAMPLING

For baseline air sampling during the manufacture of uniforms from untreated fabric, personal sampling was conducted for each SEG when volunteers could be recruited. Area samples were also collected. The purpose of the baseline sampling was to determine if there were any background levels of permethrin either from the facility or from untreated fabric.

3.4 PILOT SAMPLING

For pilot air sampling during the manufacture of uniforms from permethrin-treated fabric, personal sampling was conducted for each SEG when volunteers could be recruited. Area samples were also collected. The purpose of the pilot sampling was to determine levels of permethrin from treated fabric.

3.5 SAMPLING DATA ANALYSIS

Pilot test samples were shipped to an American Industrial Hygiene Association accredited laboratory, Bureau Veritas North America, Inc. (Novi, MI), for analysis using a modified OSHA 2063 method. Because of unplanned logistical and financial issues, samples were held longer than 2 weeks prior to analysis, but a storage and stability test was conducted to ensure the samples were still representative of the masses collected from the site visits. The storage and stability test was conducted to mimic sample storage conditions in this study. A mass of 5 µg was chosen to spike on the media, as it was near the limit of detection (1 µg).

3.6 STATISTICAL ANALYSIS

According to Milz and Mulhausen (2006) industrial hygiene sampling data typically follow a log-normal distribution. When the data were found to be log-normal, parametric inferential statistics were used to determine the 95% upper confidence limit for the estimated upper 95th_percentile exposure (the concentration at which 95% of exposures would be below that concentration) according to guidance discussed by Milz and Mulhausen⁷. All sample results were tested for log-normality ($\alpha=0.05$ level of significance) using IHSTAT: v. 235, December 2013. IHSTAT. When the data were not censored, IHSTAT, an application that calculates a variety of exposure statistics, was also used to calculate descriptive and inferential statistics⁸.

When the data were highly censored (i.e., 50-80% of the samples below the detection limit), the geometric mean (GM), geometric standard deviation (GSD), and arithmetic mean (AM) were calculated using a maximum likelihood estimation according to guidance by Finkelstein and Verma (2001) using Microsoft Excel®.⁹ The 95th percentile exposure and upper tolerance limit were calculated from the estimated GM and GSD according to guidance by Hewett (2006).¹⁰

3.7 SAFETY DETERMINATION

Once laboratory testing was complete, the resulting data were reviewed by industrial hygienists, and the most conservative upper tolerance estimate was compared to the Permissible Exposure Limit (PEL) value for pyrethrum because specific PEL values do not exist for permethrin (or the other synthetic pyrethroids). It is common practice to compare airborne pyrethroid exposures to PEL values for pyrethrum, which is a mixture of naturally occurring pyrethrin molecules "obtained from the dried and ground flowers of the pyrethrum plant, *Chrysanthemum cinerariaefolium*".¹¹ Permethrin is a synthetic analog and is chemically and toxicologically very similar to the naturally occurring pyrethrin compounds. As with the naturally occurring pyrethrins, pyrethroids are of low toxicity, both OSHA and the American Conference of Governmental Industrial Hygienists (ACGIH) have promulgated PEL values for pyrethrum of 5 mg/m³. This comparison was intended to demonstrate whether exposures to garment workers while they are producing uniforms from permethrin-treated fabric are above or below levels which would be a cause for a health concern.

4. RESULTS

4.1 PERMETHRIN VERIFICATION RESULTS

All four lots tested for permethrin content verification met the permethrin requirements of $0.095\text{mg}/\text{cm}^2 - 0.135\text{mg}/\text{cm}^2$. The average of all samples tested was $0.127\text{mg}/\text{cm}^2$. Full permethrin content results can be found in Appendix B.

4.2 VENTILATION RESULTS

The results of ventilation measurements and air change calculations are in Table 1.

Table 1: Facility General Ventilation

Facility	Facility Volume (ft ³)	Exhaust Air Flow (ft ³ /min)	Air Changes (hr ⁻¹)
ITS	158000	7840	3.0
UNICOR-Beaumont)	622000	65700	6.3
UNICOR-Seagoville)	230000	13000	3.4

4.3 BASELINE AIR QUALITY RESULTS

The results of baseline sampling for the three facilities are in Tables 2, 3, and 4, respectively. No results at any of the three facilities were above the detection limits; the data were 100% censored.

Table 2: ITS Baseline Sampling Summary

Sample Location	Samples Collected (n=19)	Samples Above Detection Limit	Degree Censored (%)	Range (µg/m ³)
Area	3	0	100	<0.96 - <1.1
Slit Goods*	0	---	---	---
QA/Supervisor	2	0	100	<2.2 - <4.6
Spreader	4	0	100	<2.3 - <6.5
Cutting/Sorting	3	0	100	<2.3 - <2.4
Binding/Boxing	7	0	100	<2.4 - <4.0

*Operation not conducted

Table 3: UNICOR-Beaumont Baseline Sampling Summary

Sample Location	Samples Collected (n=47)	Samples Above Detection Limit	Degree Censored (%)	Range (µg/m³)
Area	8	0	100	<1.9 - <2.3
Sorting	3	0	100	<2.6 - <3.4
Sewing	10	0	100	<2.4 - <3.3
Steamer	2	0	100	<2.1 - <2.7
Mechanic	2	0	100	<2.7 - <2.8
Leadman	4	0	100	<2.3 - <2.8
Marker*	0	---	---	---
Vacuummer	2	0	100	<2.5 - <2.6
Warehouse*	0	---	---	---
Orderly	2	0	100	<2.8 - <3.4
QA	10	0	100	<2.2 - <3.1
Correctional Officer	4	0	100	<1.9 - <2.9

*Operation not conducted

Table 4: UNICOR-Seagoville Baseline Sampling Summary

Sample Location	Samples Collected (n=50)	Samples Above Detection Limit	Degree Censored (%)	Range (µg/m³)
Area	8	0	100	<2.0 - <3.5
Sewing	19	0	100	<2.4 - <2.9
Heat Sealer	1	0	100	<5.9
Mechanic	2	0	100	<2.4 - <2.8
Leadman	6	0	100	<2.4 - <3.0
Marker	2	0	100	<2.5 - <2.8
Vacuummer	2	0	100	<2.6 - <3.1
Warehouse	1	0	100	<7.2
Orderly	1	0	100	<2.6
QA	5	0	100	<2.0 - <3.4
Correctional Officer	3	0	100	<2.7 - <3.5

*Operation not conducted

4.4 PILOT AIR QUALITY RESULTS

At the ITS facility, as shown in Table 5, two personal samples were above the detection limit, and no area samples above the detection limit. The data were so highly censored that statistical analysis was not possible to estimate an upper tolerance limit. The individual sample results from Uniformed Services University for each facility can be found in Appendix C.

Table 5: ITS Pilot Sampling Summary

Sample Location	Samples Collected (n=28)	Samples Above Detection Limit	Degree Censored (%)	Range (µg/m³)
Area	8	0	100	<1.0 - <1.3
Slit Goods	1	1	0	2.4
QA/Supervisor	5	0	100	<1.9 - <2.3
Spreader	6	0	100	<1.4 - <2.4
Cutting/Sorting	5	0	100	<1.7 - <2.4
Binding/Boxing	3	1	66	<2.1 - 4.9

At the UNICOR-Beaumont facility, as shown in Table 6, only one personal sample was above the detection limit. Several SEGs were not sampled due to the inability to recruit volunteers.

Table 6: UNICOR-Beaumont Pilot Sampling Summary

Sample Location	Samples Collected (n=113)	Samples Above Detection Limit	Degree Censored (%)	Range (µg/m³)
Area	20	0	100	<1.8 - <2.9
Sorting	8	0	100	<2.1 - <3.1
Sewing	64	1	98	<2.0 - <2.8
Steamer*	0	---	---	---
Mechanic*	0	---	---	---
Leadman	7	0	100	<2.0 - <3.1
Marker*	0	---	---	---
Vacuum*	0	---	---	---
Warehouse*	0	---	---	---
Orderly	3	0	100	<2.7 - <4.1
QA	3	0	100	<2.6 - <3.5
Correctional Officer	8	0	100	<2.3 - <3.1

*Unable to recruit volunteers

As shown in Table 7, there were 33 personal samples above the detection limit at the UNICOR-Seagoville facility. All SEGs were highly (50-80%) or severely (>80%) censored with the exception of the Heat Sealer SEG.

Table 7: UNICOR-Seagoville Pilot Sampling Summary

Sample Location	Samples Collected (n=116)	Samples Above Detection Limit	Degree Censored (%)	Range ($\mu\text{g}/\text{m}^3$)
Area	16	5	69	<1.9 - 6.9
Sewing	46	20	57	<2.2 - 5.9
Heat Sealer	8	8	0	2.7 - 5.5
Mechanic	5	0	100	<2.2 - <2.7
Leadman	7	0	100	<2.2 - <3.1
Marker	6	1	83	<2.2 - <2.4
Vacuummer	2	0	100	<2.2 - <2.7
Warehouse	2	0	100	<2.7 - <5.7
Orderly*	0	---	---	---
QA	14	4	72	<2.1 - 4.5
Correctional Officer	10	0	100	<2.4 - <3.7

*Unable to recruit volunteers

4.5 SAMPLING DATA ANALYSIS RESULTS

The storage and stability testing showed that over a 72-day period of storage, recovery of permethrin from the media had an arithmetic mean agreement with the known mass of $5\mu\text{g}$ of 104% with 9% coefficient of variation. The test showed that permethrin is very stable at least out to 72 days.

4.6 STATISTICAL ANALYSIS RESULTS

As discussed in Section 4.4, most of data from three pilot sampling locations was so highly censored that statistical analysis was not possible to estimate an upper tolerance limit. However, three of the SEGs at the UNICOR-Seagoville facility had enough samples above detection to estimate the upper tolerance limits (Table 8).

Table 8: UNICOR-Seagoville Pilot Upper Tolerance Estimates

Sample Location	n	n'	GM	GSD	AM	Range ($\mu\text{g}/\text{m}^3$)	W-test	X₉₅	UTL_{95,95}
QA	14	4	1.9	1.5	2.1	<2.1 - 4.5	0.934	3.9	18.0
Sewing	45	20	2.3	1.5	2.5	<2.2 - 5.9	0.954	4.5	6.1
Heat Sealing	8	8	4.3	1.3	4.0	2.7 - 5.5	0.875	6.0	8.9

n = Number of Samples Collected; n' = Number of Non-censored Samples

GM = Geometric Mean; GSD = Geometric Standard Deviation

AM = Arithmetic Mean; X₉₅ = Estimated Upper 95th-Percentile Exposure

UTL_{95,95} = Estimated Upper 95-% Confidence Limit for X₉₅

For the three SEGs at UNICOR-Seagoville, the Shapiro-Wilk (W-test) statistic was greater than the respective critical values ($\alpha = 0.05$ level of significance) of those three SEGs, indicating log-normal distributions. The upper 95% confidence limit of the 95th-percentile exposure estimate ranged from 6.1-18 $\mu\text{g}/\text{m}^3$.

4.7 SAFETY DETERMINATION

The PEL for pyrethrum promulgated by OSHA is an 8-h time-weighted average of 5000 $\mu\text{g}/\text{m}^3$. Comparing the most conservative estimate of the upper tolerance limit shown in Table 8 (18 $\mu\text{g}/\text{m}^3$) with this PEL indicates that with 95% confidence, 95% of the exposures to permethrin in the QA similar exposure group were 278 times lower than the PEL (or 0.4% of the PEL) for the similar compounds found in pyrethrum.

5. DISCUSSION AND CONCLUSIONS

The objective of this study was to quantify airborne permethrin during the manufacture of Army Combat Uniforms using pre-treated fabric. SEGs with measurable and consistent exposures to permethrin were QA, Sewing, and especially Heat Sealing. Heating the fabric appears to increase airborne permethrin to above the detection limit most consistently. The UNICOR facility in Seagoville had the greatest number of results above the detection limit of the three facilities. Additionally, the operations were most similar between the two UNICOR facilities. The most significant differences between those two facilities were the use of the heat sealer in the Seagoville facility, the larger facility volume in the Beaumont facility, and the lower general dilution rate of 3.4 air changes per hour for the Seagoville facility versus the 6.3 air changes per hour at the Beaumont facility. All three factors may have contributed to the greater number of results above the detection at the Seagoville facility.

The most conservative upper tolerance estimate in this study ($18 \mu\text{g}/\text{m}^3$) was found to be only .04% of the PEL established for a mixture of similar compounds (pyrethrum), in the absence of a PEL specific to permethrin. An additional search and review of literature found that in 2011 the US EPA did determine there is a common mechanism for all pyrethrins and pyrethroids¹². Therefore, the use of the Pyrethrum PEL promulgated by OSHA is appropriate for comparison purposes when judging safe exposure levels. While the most conservative estimate of the airborne concentration of permethrin in these facilities is suggestive of levels of safely below occupational exposure concern, this is based on a PEL not specific to permethrin.

As an additional precaution, data were forwarded to the US Army Public Health Command (USPHC) for review to determine safe exposure levels specific to airborne permethrin. Because cutting and sewing uniforms does not involve DoD personnel, USPHC recommended that a Workplace Environmental Exposure Level be developed for permethrin. Consequently, the American Industrial Hygiene Association (AIHA) Guideline Foundation Workplace Environmental Exposure Levels® (WEELs®) provide guidance for protecting most workers from adverse health effects related to occupational chemical exposures. This avenue is being pursued and an addendum to this report will be published once the PEL for permethrin is established. The estimated timeframe for the establishment of new WEEL values is 1 to 1.5 years.

Internet searches have revealed little on permethrin exposure limits. Most permethrin products list the OEL for pyrethrum within safety data sheets. A small number of safety data sheets included internally developed OELs for permethrin. The companies that included supplier/internally developed OELs were, McLaughlin Gormley King Company ($\text{OEL}=10 \text{ mg}/\text{m}^3$)¹³, Ragan and Massey, Inc. ($10 \text{ mg}/\text{m}^3$)¹⁴, GlaxoSmithKline UK (8-h time weighted average = $200 \mu\text{g} / \text{m}^3$)¹⁵, Wisconsin Pharmacal Company ($10 \text{ mg}/\text{m}^3$)¹⁶, and Syngenta Crop Protection, Inc. ($10 \text{ mg}/\text{m}^3$)¹⁷. Comparing the most conservative estimate of the upper tolerance limit of $18 \mu\text{g}/\text{m}^3$ found in this study with the lowest 8-h time weighted average of $200 \mu\text{g} / \text{m}^3$ indicates that the levels of permethrin in the air were over 10 times lower than even the most conservative exposure limit set by industry.

This study was conducted to determine worker exposure to airborne permethrin when cutting and sewing permethrin treated fabric. Based upon the OSHA promulgated PEL $5000 \mu\text{g}/\text{m}^3$ for

pyrethrum and the lowest exposure limit of 200 $\mu\text{g}/\text{m}^3$ set by industry, data collected during cutting and sewing operations of pre-treated fabrics as part of this study indicate airborne exposure to permethrin fall below levels of concern. It is recommended that industry incorporate local standard operating practices to monitor permethrin levels and facility air changes.

This document reports research undertaken at the U.S. Army Natick Soldier Research, Development and Engineering Center, Natick, MA, and has been assigned No. NATICK/TR-16/020 in a series of reports approved for publication.

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14. MSDS, COMPARE-N-SAVE® HOME PEST CONTROL RTU SPRAY
15. MSDS, NIX DERMAL CREAM
16. MSDS, Coleman Permethrin Aerosol
17. MSDS, PRELUDE

APPENDIX A
EVALUATION OF PERMETHRIN TREATED FABRIC MATERIALS:
EXTRACTION AND ANALYSIS BY GAS CHROMATOGRAPHY-MASS
SPECTROMETRY

Note: The conditions described in this method are optimum for the gas chromatograph employed. These conditions may vary based on the gas chromatograph used. The carrier gas flow rate shall be adjusted so the elution of the first permethrin isomer is greater than 5 minutes. Alternate methods of extraction and analysis are subject to government approval and laboratory cross correlation prior to implementation.

A. Apparatus.

A.1 Analytical Balance. 0.0001g sensitivity, Mettler Toledo, or equal

A.2 Analytical Balance. 0.000001g sensitivity, Mettler Toledo, or equal

A.3 Glassware.

A.3.1 10-100mL volumetric flasks

A.3.2 Funnel

A.3.3 Pipettes

A.4 Automatic Die Cutter. Freeman Atom, or equal

A.4.1 Three Inch Cutting Die. 3 inch diameter circular steel die cutter

A.5 Extraction Apparatus.

A.5.1 Accelerated Solvent Extractor (ASE) Dionex Corporation or equal

A.5.1.1 Liquid Nitrogen Cylinder to Deliver High Pressure Gas, 230psi

A.5.1.2 Complete Extraction Cells, 22mL

A.5.1.3 Cellulose filters, 1.98cm

A.5.1.4 40mL Amber Glass Collection Vials

A.5.1.5 Solvent Resistant Teflon-Silicone Coated Septa

A.5.1.6 3mm-4mm borosilicate glass beads

A.5.2 Soxhlet.

A.5.2.1 Electric heater with variable control

A.5.2.2 Heat resistant glass flask when using Soxhlet extractor. The flask shall be a 250mL, flat or round bottom, and single neck.

A.5.2.3 Extractor condenser

A.5.2.4 Boiling condenser

A.5.2.5 Cellulose extraction thimbles

A.6 Agilent 6890N (G1530N) Series Gas Chromatograph. Gas Chromatograph equipped with ChemStation software, or equal

A.6.1 Carrier Gas Cylinder, Appropriate Regulator Set at 80psi

A.6.2 Hewlett-Packard Capillary Column, 5% Phenyl Methyl Siloxane/30.0m x 250µm 0.25µm nominal, 325°C Max, or equal.

A.6.3 Split Inlet Liner, Packed with Silanized Glass Wool/5mm

A.6.4 Injector Microliter Syringe, Capable of Delivering 1µL

A.6.5 GC Amber Injection Vials and Rinse Vials

A.7 Agilent Series 5973N (G2579A) Mass Spectrometer, or equal.

A.7.1 Performance Turbo Pump MSD (EI Mode), or equal

A.8 Ultrasonic Cleaner. Branson, or equal

A.9 High Temperature Convection Oven. 500°C Max

A.10 Refrigerator Storage. 4°C

B. Reagents.

B.1 Permethrin Analytical Standard. Permethrin standard shall be $\geq 97\%$, mixture of Cis/Trans Isomers. Permethrin standards are available from FMC Agricultural Products; Princeton, New Jersey 08543; FMC reference #33297; 97% purity/specified technical, or equal

B.2 Solvent Mixture. Solvent mixture shall be 80% Acetonitrile/Analytical Grade and 20% Methanol/Analytical Grade

B.3 High Purity Helium Carrier Gas. Carrier gas shall be $\geq 99.999\%$

B.4 Cleaning Solutions. Cleaning solutions shall be as follows:

B.4.1 Micro-90 Ultra Cleaning Solution, or equal

B.4.2 Reversed Osmosis Water, 98% Rejection Rate

C. Calibration of Apparatus.

C.1 Analytical Balance.

C.1.1 Pre-Weighing Procedures. Prior to weighing, initiate the internal weight calibration function or use an external certified weight set to verify that the balance is operating properly.

C.1.2 Manufacturer Calibrations. Obtain manufacturer certifications within 12 months prior to taking measurement.

C.2 Gas Chromatography equipped with Mass Selective Detector (See A.6, A.7)

C.2.1 Perform the manufacturers recommended calibration procedures prior to analyses.

C.2.2 Before samples or required blanks can be analyzed, the instrument must meet the initial calibration acceptance criteria (see G).

C.3 Cleaning Techniques. Establish cleaning techniques to ensure that no permethrin carries over from experiment to experiment. The techniques listed below have been determined to be suitable:

C.3.1 Evaporate excess solvent from extraction glassware and wash using conventional methods. (see B.4)

C.3.2 Bake off residual organic substances from glassware in high temperature convection oven, 500°C, for three to six hours. (see A.9)

C.3.3 Sonicate A.S.E. Cells in the solvent that was used for the extraction. (see A.8)

D. Sampling and Test Specimens.

D.1 Sample size. The sample size (Class 2 trouser) to be tested shall be selected in accordance with ANSI/ASQ Z1.4, Special Inspection Levels S-1 and AQL of 1.5.

D.2 Test specimens.

D.2.1 From each sample garment being evaluated (unlaundered, after 20 and after 50 launderings), select three 3 inch diameter specimens (use a 3 inch circular cutting die having surface area of 45.6037cm²) for each test condition. Cut specimens from single ply areas so that no two specimens shall contain the same warp and filling yarns (for example, for the blouse areas-front left, front right, back, right sleeve, left sleeve; and for the trouser areas-front left leg, back left leg, right front leg, back front leg, and front left or right fly). Specimens for the measurement of permethrin content after laundering shall be cut after the finished garment has been laundered according to AATCC 135, 3, V, III to the specified number of cycles. Laundered specimens shall be cut from different ply areas across the garment.

D.2.2 Weigh each specimen to the nearest milligram (see A.1).

E. Standards.

E.1 Standard Preparation.

E.1.1 Prepare six concentrations of permethrin standards which are 20, 50, 75, 100, 150, and 200ng/μL, [1ng/μL is equal to 1 part-per-million (ppm)]

E.1.2 Using the balance specified in A.2, weigh 10mg $\pm$ 1mg of permethrin crystals and place into a 50mL volumetric flask and fill with 80% acetonitrile/20% methanol solvent to obtain

the standard of 200ng/μL. Make all appropriate dilutions from this flask to obtain the additional standards.

E.1.3 Calculate the actual concentrations of the standards based on the weight of the permethrin.

F. Extraction Procedure (see A.5)

F.1 ASE

F.1.1 Preparing Specimens. Roll each specimen and place into an ASE cell fitted with a cellulose filter. Fill the void with glass beads to conserve solvent. Place all cells onto ASE cell tray.

F.1.2 Quality Control. Extract a specimen blank for every run to detect if any carry over of permethrin is significant.

F.1.3 Accelerated Solvent Extraction Procedures.

F.1.3.1 Parameters.

Cell Size 22mL

Collection vials 60mL, light blocking/amber

Solvent 80% Acetonitrile, 20% Methanol

Approximate Gas Pressures:

System 50 psi

System Solvent 10 psi

Oven Compression 130 psi

Parameters:

Preheat 0 min

Heat 5 min @ 100°C

Static w/Solvent 10 min @ 1500 psi

Flush Volume 90%

Purge 90 sec

Cycles 2

F.1.3.2 Preparation for analyses. Dilute or concentrate each vial to 40mL and prepare a 1mL aliquot from every specimen extraction for GC analysis. Permethrin recovery must be 95% or greater (see F.4).

F.2 Soxhlet. Place each specimen into cellulose Soxhlet extraction thimble. Add 160mL of the acetonitrile/methanol mixture and boiling chips into a 250mL flask. Assemble the Soxhlet apparatus and extract the permethrin treated specimens for 6 hours or until and extraction recovery of 95% or greater has been achieved (see F.4). Concentrate the extract by roto-evaporation, or equal, at 35°C to a final volume of 40mL.

F.3 Storage. After the specimens are extracted, store in light blocking amber vials in refrigerator until ready to inject (see A.10). Specimen extractions shall be stored in a refrigerator for no longer than three months. When ready to analyze, allow the temperature of the GC vials to equilibrate in the area of evaluation before injection into GC.

F.4 Extraction Efficiency.

F.4.1 Select three random specimens from any permethrin treated fabric sample and perform three consecutive extractions.

F.4.2 Quantify the level of permethrin recovered from each specimen for each consecutive extraction, through GC/MS analysis.

F.4.3 Verify that the percent recovery of permethrin for any specimen size and composition, is 95% or greater by comparing the recovery level from the first extraction, to that of subsequent extractions. Combine the permethrin levels obtained from each of the three extractions, if the initial extraction yields permethrin levels 95% or greater than the total percent of permethrin extracted three sequential times, then the extraction efficiency is 95%

or greater. Note - To ensure that the extraction efficiency is being accurately calculated, the permethrin levels in the second and third extraction should be minimal, and the permethrin level by the third extraction should be trace or zero.

Note: Initial verification of extraction efficiency of this test method must be performed. Once an extraction efficiency of 95% or greater is established, no further demonstration of the extraction efficiency is needed.

G. Analytical Procedure.

G.1 Quality Control. Laboratory blanks that contain no analyte are used to ensure specimens are free of contaminants or to ensure there is no cross contamination during a run. Inject a blank containing 80% acetonitrile/20% methanol before every set of standards and before and after every ten specimens. If any blank, after multiplying concentration by five, is greater than any specimen result, the specimen data points are invalid and a system check must be run to identify the source of the carry over. After system maintenance has been performed, repeat injections of the standards for the calibration curve, new blanks, and new aliquots of the specimens affected by the previous carryover.

G.2 Standard Injection.

G.2.1 All six permethrin standards will be injected at the beginning and at the end of each series of specimens to "bracket" the specimen injections. Check linearity of the standards for each set of injections by plotting the responses (area counts) on the x-axis vs. the calculated standard concentrations on the y-axis. A 3rd order polynomial regression line with R-squared value of 0.99 or greater is acceptable. Derive the equation of the 3rd order polynomial for sample calculations.

G.3 Specimen Injection. Run specimen injections in duplicate. Sample extracts, standards, and blanks must be analyzed within an analytical sequence such as listed below:

Initial calibration (Standards)

Instrument blank at the end of the initial calibration

Specimen Series 1 (extracts 1-10, 1st quantitation)

Instrument blank

Standard Series 1

Instrument blank

Specimens Series 2 (extracts 1-10, 2nd quantitation)

Instrument blank

Standard Series 2

Instrument blank

Subsequent specimen series, (ex. 11-20, including blanks, and standard series)

Final calibration (Standards)

Note: After the initial calibration, the analytical sequence may continue as long as acceptable instrument blanks and the standards are analyzed at the required frequency. If any specimen count does not fall on the standard calibration curve, the evaluator may dilute that specimen by 1:10 and re-run; calculations of the permethrin level must be adjusted using the factor of 10.

G.4 Gas Chromatograph/Mass Spectrometer Parameters. (see A.6)

G.4.1 Injection procedures.

G.4.1.1 Place all GC vials into auto sampler tray. To avoid vapor pressure differences, all vials must be at room temperature and containing identical volumes.

G.4.1.2 Inject 1µL into the Gas Chromatograph equipped with Mass Spectrometer.

Use high purity helium carrier gas (see B.3) and appropriate column.

G.4.1.3 Ensure that rinse vials in the injector port contain 80% acetonitrile/20% methanol above the minimum solvent line.

G.4.2 Instrument Settings. The following parameters will be used in the analysis:

Oven Temperature 250 °C

Injector Temperature 275 °C

Detector Temperature 280 °C

Injection volume 1µL

Carrier Gas Flow Rate 1.3 mL/min

GC Run Time 10 min

Split Ratio 3:1

MS Single Ion Monitoring

Scan Parameters EM Voltage Gain Factor of 1

Real Time Plot 10 min

Resolution Low

Solvent Delay 4 min

Start Time 4 min, 4.26 Cycles/sec

Ions Monitored 183 (quantitation), Dwell 100

163 (confirmatory), Dwell 100

G.4.3 Evaluation Procedures.

G.4.3.1 Quantify the permethrin content detected by the mass spectrometer by extracting ion chromatograms 183 (quantitation ion) and 163 (confirmatory ion).

G.4.3.2 Integrate permethrin peaks manually from baseline to baseline using the software, or generation of report.

H. Calculations.

H.1 Permethrin Concentration. The permethrin concentration will be calculated from the area counts of the chromatographic curve and expressed in terms of mass permethrin per surface area (mg/cm²), with the option of expressing in terms of weight permethrin per weight of specimen (W/W%):

H.1.1 Concentration. The concentration of permethrin in milligrams per square centimeter shall be calculated as follows:

Concentration (mg/cm²) =

40mL x (ax³ + bx² + cx + d) x (1,000 µL/1mL) x 1mg/1,000,000ng x (1/45.6037cm²)

Where:

40mL = Final Volume

a, b, c and d = numbers derived from 3rd degree polynomial equation from standard series following specimen series

x = area count of the specimen curve

45.6037cm² = area of specimen

H.1.2 Conversion to Permethrin Weight Percent Content (W/W%).

Concentration (W/W%) = [Concentration (mg/cm²) multiplied by (surface area) cm² divided by (weight of specimen) mg] multiplied by 100.

I. Report. Report the individual concentration for each specimen in milligrams per square centimeter permethrin to the nearest 0.001mg, (no individual specimen results shall fall outside of the minimum to maximum range of the permethrin levels as specified in paragraph 3.4.1). A single retest shall be allowed; when a single specimen fails, a new sample with complete set of specimens shall be sampled and tested. The retest shall be used to rate pass or fail

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APPENDIX B

PERMETHRIN CONTENT RESULTS

(Reprint of original)



Natick Soldier Research, Development and Engineering Center
Warfighter Directorate
Textile Materials Evaluation Team
15 Kansas Street
Natick, MA 01760

CUSTOMER: M.Perry
CONTRACT: W911QY-14-F-1048
FABRIC: Mantech - Carlisle Finishing/Burlington
FOR USE IN: ACUP

PRODUCT: Burlington - ManTech
LOT #: Pieces 1-3 0x

Initially -
PERMETHRIN MIN: 0.095mg/cm²
PERMETHRIN MAX: 0.135mg/cm²

TEST COMPLETED: 23-Dec-14

TEST METHOD: As In GL/PD-07-13C 4OCT2011 and GL/PD-07-14C 4OCT2011

LAB REPORT: 2498

Sample Identification	Specimen #	mg/cm ²	Avg.
Job#2130-W911QY-14-F-1048-Mantech-fabric Roll-FAT-1-0x	1	0.128	0.127
	2	0.135	
	3	0.118	
Job#2130-W911QY-14-F-1048-Mantech-fabric Roll-FAT-2-0x	1	0.139	0.130
	2	0.127	
	3	0.123	
Job#2130-W911QY-14-F-1048-Mantech-fabric Roll-FAT-3-0x	1	0.127	0.134
	2	0.141	
	3	0.135	

I certify that the above tests were performed in accordance with the specification GL/PD-07-13C 4OCT2011 and GL/PD-07-14C 4OCT2011 Permethrin Test Method and that the reported results are true, valid and applicable to the samples tested.

Textile Technologist: Amy L. Johnson
Team Leader: Luisa DeMoraes

Date: 23-Dec-14



Natick Soldier Research, Development and Engineering Center
Warfighter Directorate
Textile Materials Evaluation Team
15 Kansas Street
Natick, MA 01760

CUSTOMER: M.Perry
CONTRACT: W911QY-14-F-1048
FABRIC: Mantech - Carlisle Finishing/Burlington
FOR USE IN: ACUP

PRODUCT: Burlington - ManTech
LOT #: Pieces 1-3 20x

After 20 launderings (20x) -
PERMETHRIN MIN: 0.025mg/cm²
PERMETHRIN MAX: 0.135mg/cm²

TEST COMPLETED: 16-Jan-15
TEST METHOD: As In GL/PD-07-13C 4OCT2011 and GL/PD-07-14C 4OCT2011
LAB REPORT: 2528

Sample Identification	Specimen #	mg/cm ²	Avg.
Job#2130-W911QY-14-F-1048-Mantech-fabric Roll-FAT-1-20x	1	0.034	0.034
	2	0.034	
	3	0.034	
Job#2130-W911QY-14-F-1048-Mantech-fabric Roll-FAT-2-20x	1	0.033	0.033
	2	0.032	
	3	0.034	
Job#2130-W911QY-14-F-1048-Mantech-fabric Roll-FAT-3-20x	1	0.032	0.033
	2	0.034	
	3	0.033	

I certify that the above tests were performed in accordance with the specification GL/PD-07-13C 4OCT2011 and GL/PD-07-14C 4OCT2011 Permethrin Test Method and that the reported results are true, valid and applicable to the samples tested.

Textile Technologist: Amy L. Johnson
Team Leader: Luisa DeMoraes

Date: 16-Jan-15



Natick Soldier Research, Development and Engineering Center
Warfighter Directorate
Textile Materials Evaluation Team
15 Kansas Street
Natick, MA 01760

CUSTOMER: M.Perry
CONTRACT: W911QY-14-F-1048
FABRIC: Mantech - Carlisle Finishing/Burlington
FOR USE IN: ACUP

PRODUCT: Burlington - ManTech
LOT #: Pieces 1-3 50x

After 50 launderings (50x) -
PERMETHRIN MIN: N/A
PERMETHRIN MAX: N/A

TEST COMPLETED: 30-Jan-15

TEST METHOD: As In GL/PD-07-13C 4OCT2011 and GL/PD-07-14C 4OCT2011

LAB REPORT: 2562

Sample Identification	Specimen #	mg/cm ²	Avg.
Job#2130-W911QY-14-F-1048-Mantech-fabric Roll-FAT-1-50x	1	0.014	0.014
	2	0.013	
	3	0.014	
Job#2130-W911QY-14-F-1048-Mantech-fabric Roll-FAT-2-50x	1	0.014	0.013
	2	0.013	
	3	0.013	
Job#2130-W911QY-14-F-1048-Mantech-fabric Roll-FAT-3-50x	1	0.015	0.013
	2	0.012	
	3	0.013	

I certify that the above tests were performed in accordance with the specification GL/PD-07-13C 4OCT2011 and GL/PD-07-14C 4OCT2011 Permethrin Test Method and that the reported results are true, valid and applicable to the samples tested.

Textile Technologist: Amy L. Johnson
Team Leader: Luisa DeMoraes

Date: 30-Jan-15



Natick Soldier Research, Development and Engineering Center
Warfighter Directorate
Textile Materials Evaluation Team
15 Kansas Street
Natick, MA 01760

CUSTOMER: M.Perry
CONTRACT: W911QY-14-F-1048
FABRIC: Mantech - Carlisle Finishing/Burlington
FOR USE IN: ACUP

PRODUCT: Burlington - ManTech
LOT #: 2

Initially -
PERMETHRIN MIN: 0.095mg/cm²
PERMETHRIN MAX: 0.135mg/cm²

TEST COMPLETED: 6-Feb-15

TEST METHOD: As In GL/PD-07-13C 4OCT2011 and GL/PD-07-14C 4OCT2011

LAB REPORT: 2570

Sample Identification	Specimen #	mg/cm ²	Avg.
Job#2154-CF-W911QY-14-F-1048-Mantech-Fabric Roll-Lot#2-1-0x	1	0.115	0.119
	2	0.126	
	3	0.117	
Job#2154-CF-W911QY-14-F-1048-Mantech-Fabric Roll-Lot#2-2-0x	1	0.123	0.126
	2	0.132	
	3	0.122	
Job#2154-CF-W911QY-14-F-1048-Mantech-Fabric Roll-Lot#2-3-0x	1	0.127	0.133
	2	0.141	
	3	0.129	

I certify that the above tests were performed in accordance with the specification GL/PD-07-13C 4OCT2011 and GL/PD-07-14C 4OCT2011 Permethrin Test Method and that the reported results are true, valid and applicable to the samples tested.

Textile Technologist: Amy L. Johnson
Team Leader: Luisa DeMoraes

Date: 6-Feb-15



Natick Soldier Research, Development and Engineering Center
Warfighter Directorate
Textile Materials Evaluation Team
15 Kansas Street
Natick, MA 01760

CUSTOMER: M.Perry
CONTRACT: W911QY-14-F-1048
FABRIC: Mantech - Carlisle Finishing/Burlington
FOR USE IN: ACUP

PRODUCT: Burlington - ManTech
LOT #: 3

Initially -
PERMETHRIN MIN: 0.095mg/cm²
PERMETHRIN MAX: 0.135mg/cm²

TEST COMPLETED: 6-Feb-15

TEST METHOD: As In GL/PD-07-13C 4OCT2011 and GL/PD-07-14C 4OCT2011

LAB REPORT: 2571

Sample Identification	Specimen #	mg/cm ²	Avg.
Job#2155-CF-W911QY-14-F-1048-Mantech-Fabric Roll-Lot#3-1-0x	1	0.120	0.125
	2	0.134	
	3	0.122	
Job#2155-CF-W911QY-14-F-1048-Mantech-Fabric Roll-Lot#3-2-0x	1	0.124	0.128
	2	0.137	
	3	0.124	
Job#2155-CF-W911QY-14-F-1048-Mantech-Fabric Roll-Lot#3-3-0x	1	0.128	0.131
	2	0.134	
	3	0.132	

I certify that the above tests were performed in accordance with the specification GL/PD-07-13C 4OCT2011 and GL/PD-07-14C 4OCT2011 Permethrin Test Method and that the reported results are true, valid and applicable to the samples tested.

Textile Technologist: Amy L. Johnson
Team Leader: Luisa DeMoraes

Date: 6-Feb-15



**Natick Soldier Research, Development and Engineering Center
Warfighter Directorate
Textile Materials Evaluation Team
15 Kansas Street
Natick, MA 01760**

CUSTOMER: M.Perry
CONTRACT: W911QY-14-F-1048
FABRIC: Mantech - Carlisle Finishing/Burlington
FOR USE IN: ACUP

PRODUCT: Burlington - ManTech
LOT #: 4

Initially -
PERMETHRIN MIN: 0.095mg/cm²
PERMETHRIN MAX: 0.135mg/cm²

TEST COMPLETED: 11-Feb-15

TEST METHOD: As In GL/PD-07-13C 4OCT2011 and GL/PD-07-14C 4OCT2011

LAB REPORT: 2572

Sample Identification	Specimen #	mg/cm ²	Avg.
Job#2158-CF-W911QY-14-F-1048-Mantech-Fabric Roll-Lot#4-1-0x	1	0.111	0.117
	2	0.127	
	3	0.113	
Job#2158-CF-W911QY-14-F-1048-Mantech-Fabric Roll-Lot#4-2-0x	1	0.108	0.120
	2	0.127	
	3	0.123	
Job#2158-CF-W911QY-14-F-1048-Mantech-Fabric Roll-Lot#4-3-0x	1	0.126	0.128
	2	0.130	
	3	0.127	

I certify that the above tests were performed in accordance with the specification GL/PD-07-13C 4OCT2011 and GL/PD-07-14C 4OCT2011 Permethrin Test Method and that the reported results are true, valid and applicable to the samples tested.

Textile Technologist: Amy L. Johnson
Team Leader: Luisa DeMoraes

Date: 11-Feb-15

APPENDIX C

INDIVIDUAL SAMPLE RESULTS

Table C-1: ITS Permethrin Treated Fabric Sample Results

Results (mg/m ³)					
Area	Cutting / Sorting	QA	Spreader	Binding / Boxing	Slit Goods
<0.0010	<0.0018	<0.0023	<0.0024	<0.0021	0.0024
<0.0011	<0.0023	<0.0021	<0.0021	0.0049	
<0.0012	<0.0018	<0.0019	<0.0014	<0.0021	
<0.0011	<0.0017	<0.0021	<0.002		
<0.0013	<0.002	<0.002	<0.0021		
<0.0012					
<0.0012					
<0.0012					

Table C-2: UNICOR-Beaumont Treated Fabric Sample Results

Results (mg/m ³)								
Correctional								
Area	Sorting	Orderly	Leadman	Officer	QA	Sewing		
<0.0021	<0.0027	<0.0028	<0.0026	<0.0027	<0.0035	0.0028	<0.0029	<0.0033
<0.0022	<0.0025	<0.0027	<0.0026	<0.0026	<0.0028	<0.0025	<0.0028	<0.0029
<0.0024	<0.0026	<0.0041	<0.0026	<0.0023	<0.0026	<0.0024	<0.0027	<0.0029
<0.0021	<0.0025		<0.0020	<0.0023		<0.0025	<0.0024	<0.0027
<0.0023	<0.0021		<0.0034	<0.0025		<0.0024	<0.0026	<0.0030
<0.0023	<0.0030		<0.0031	<0.0031		<0.0030	<0.0027	<0.0031
<0.0023	<0.0031		<0.0028	<0.0027		<0.0034	<0.0026	<0.0028
<0.0022	<0.0027			<0.0026		<0.0026	<0.0020	<0.0027
<0.0025						<0.0025	<0.0024	
<0.0018						<0.0025	<0.0027	
<0.0020						<0.0025	<0.0026	
<0.0019						<0.0026	<0.0025	
<0.0018						<0.0025	<0.0029	
<0.0019						<0.0026	<0.0029	
<0.0018						<0.0026	<0.0030	
<0.0017						<0.0026	<0.0048	
<0.0021						<0.0026	<0.0038	
<0.0024						<0.0025	<0.0039	
<0.0021						<0.0025	<0.0039	
<0.0021						<0.0025	<0.004	
						<0.0024	<0.0041	
						<0.0027	<0.0041	
						<0.0022	<0.0029	
						<0.0026	<0.0025	
						<0.0027	<0.0038	
						<0.0057	<0.0026	
						<0.0028	<0.0029	
						<0.0027	<0.0029	

Table C-3: UNICOR-Seagoville-Treated Fabric Sample Results

Results (mg/m ³)											
Area	Leadman	Marking	Mechanic	Correctional Officer	QA	Sewing	Heat Sealing	Ironing	Vacuummer	Warehouse	
<0.0023	<0.0031	<0.0031	<0.0027	<0.0031	<0.0032	<0.0029	0.0031	0.0055	<0.0026	<0.0022	<0.0027
<0.0023	<0.0028	<0.0027	<0.0025	<0.0035	<0.0032	<0.003	0.0022	0.0052	0.0031	<0.0027	<0.0057
<0.0022	<0.0023	0.0024	<0.0022	<0.0027	0.0034	<0.0031	0.0024	0.0052			
0.0069	<0.0025	<0.0022	<0.0026	<0.0027	<0.0028	<0.0034	0.0039	0.0044			
<0.0023	<0.0027	<0.0026	<0.0026	<0.0029	<0.0022	<0.0029	<0.0026	0.0040			
<0.0023	<0.0022	<0.0026		<0.0037	0.0045	<0.0030	0.0025	0.0027			
<0.0024	<0.0026			<0.0025	<0.0027	<0.0027	0.0028	0.0040			
<0.0019				<0.0024	<0.0019	<0.0028	<0.0022	0.0042			
<0.0019				<0.0028	0.0026	0.0030	0.0034				
0.0027				<0.0037	0.0024	0.0050	0.0031				
0.0023					<0.0021	0.0050	0.0038				
<0.0020					<0.0027	<0.0022	<0.0026				
<0.0020					<0.0026	0.0032	<0.0027				
<0.0020					<0.0027	0.0039	<0.0025				
0.0027						<0.0022	0.0033				
<0.0020						<0.0022	<0.0026				
<0.0020						<0.0024	0.0030				
						<0.0021					
						<0.0027					
						<0.0026					
						<0.0026					
						0.0059					
						<0.0026					
						0.0023					
						0.0036					
						<0.0022					
						0.0025					
						<0.0022					