Technical Journal, University of Engineering and Technology (UET) Taxila, Pakistan Vol. 24 No. 1-2019
ISSN:1813-1786 (Print) 2313-7770 (Online)

Effect of Laundering on Tensile Strength of Chemical Protective Clothing Materials

M.Ijaz[1], S.Kalsoom[2], N.A. Akhtar[3]

[1] *Lahore College for Women University, Lahore, Pakistan*
[2] *College of Home Economics, Gulberg, Lahore, Pakistan*
[3] *University of the Punjab, Lahore, Pakistan*
[1] mehreenijaz@hotmail.com

Abstract- The present study aims at determining the effect of laundering on the tensile strength of locally manufactured chemical protective clothing materials used in various fertilizer-manufacturing units in Pakistan. The research work was performed at Nishat Mills Limited (Dyeing and Finishing Unit). These samples were evaluated for their tensile strength both in the warp and weft directions at various laundering intervals by following Strip method ISO-13934-1. All the data was analyzed through SPSS version 22. As the data was observed on repeated washing cycles, repeated measurement analysis of variance (ANOVA) was applied to measure the significance of various washes on tensile strength of samples. A decreasing trend was observed in the tensile strength of all tested sample both in their warp and weft directions after various laundering intervals. Out of these, sample F showed better performance till the 20th wash as compared to the other samples due to the inherent properties of polyester fiber. The p-value (0.000) also suggested that there was a significant statistical difference in the tensile strength of samples after various laundering cycles. It was concluded that collected locally manufactured protective clothing materials were not adequate to use, as they failed to meet the required international safety standards.

Keywords- Tensile Strength, Warp Direction, Weft Direction, Protective Clothing, Laundering Intervals.

I. Introduction

A chemical worker is most likely to face certain hazards such as physical, chemical or biological at his work place [1]. Coveralls, jackets, gloves, masks and boots are used in a chemical industry to provide safety against such risks. These protective equipment must be carefully tested for their performance characteristics before every use [2-3]. Four type of chemicals such as Sulphuric acid (30% concentration in aqueous solution), Sodium hydroxide (30% concentration in aqueous solution), Xylene (undiluted) and Butanol (undiluted) were considered in this research work, as these chemicals are tested to evaluate the chemical resistance of textile materials.

Safety of the workers is very essential in every profession such as chemists, fire fighters, pesticide and food handles, medical staff, military workers, armed forces and others. It has been observed in many researches that one of the major cause for an inappropriate use of protective ensembles is their non-availability to the worker. So, it should be the responsibility of management to make sure that its workers are provided with adequate type of protective clothing. [4-5].

There is a lack of awareness among the management and staff regarding the proper and adequate use of protective clothing. It is generally seen that ensembles with non-flame resistant characteristics are worn while dealing with flammable substances [6]. With the latest technology, a wide range of chemicals, new materials and digitalization, the nature of risks associated with the work area have been changed. Thus, a great deal of attention is needed to protect the worker from contamination during the work by adequate use of protective clothing [7]. Kind of protection offered by protective clothing materials is assessed by their physical and chemical characteristics such as tensile strength, tear strength, elasticity, moisture transmission heat transfer, chemical resistance, and so on. These clothing properties individually as well as mutually create a shield in hazardous conditions for the wearer [8].

Assessment of fabric behavior is a complex phenomenon in its theoretical form so, must be verified through experimentation for its mechanical, physical, chemical and resistance characteristics [9] Tensile strength is defined as an ability of any material to resist certain pressure to pull it a part [10]. It determines the performance of fabrics under various conditions. So, the strength of clothing materials has a strong relationship with the end quality of these materials [11-12].

There is an increased awareness on the use of synthetic polymers and their potential effect on the environment has diverted the attention of manufacturers towards biodegradable polymers in the making of various products [13]. A remarkable increase has been seen in their use from 4% to 6.6 million tons from the year 2015 to 2016 and an increasing trend has been predicted to continue in coming years [14]. Polyester and cotton blended fabrics are good option to provide safety against aqueous solutions but unable to provide complete protection against toxic chemicals, if not treated with any finishing treatment [15].

Tensile behaviour of clothing materials is based on fiber arrangement including its length or diameter [16]. Woven fabrics have anisotropic properties in which different behaviors can be observed in different directions. So, it is necessary to measure the fabric both in its warp and weft directions. The impact of loading on tensile characteristics of the clothing materials is very essential and has been frequently studied by many researchers [17]. The yarn varies in its principal direction because variations exist in type and amount of twist applied, presence or absence of crimp, finishes and sizing applied over its surface. The physical characteristics of fabrics also differ in their diagonal or oblique direction [18].

II. MATERIALS AND METHODS

Locally manufactured clothing materials (n=15) used for protective coveralls were randomly collected from different chemical units in Pakistan. These materials were being used by chemical workers when dealing with hazardous chemicals. These materials were also labeled as chemical resistant by their manufacturers as their repellency index was indicated as >90 and penetration index <5. According to the test procedure ISO 6530:2005, any fabric can be considered as chemical resistant if it falls in the said penetration and repellency index. The protective clothing has to be laundered by the wearer to reuse it for many times. So, the main purpose of the study was to examine the effect of laundering on these materials at various intervals. The clothing materials are mentioned in the Table I along with their construction parameters.

TABLE I CONSTRUCTION PARAMETERS OF COLLECTED SAMPLES

Sample Code	Fiber content	Weave type	Fabric Mass (GSM)	Yarn Count (warp / weft per inch)
A	Cotton 15% Polyester 85%	Twill	153	136x80
B	Cotton 100%	Twill	257	140x88
C	Cotton 14% Polyester 86%	Plain	151	94x66
D	Cotton 100%	Twill	208	122x48
E	Cotton 100%	Plain	152	56x48
F	Cotton 1% Polyester 99%	Plain	160	75x50
G	Cotton 100%	Plain	141	110x80
H	Cotton 97% Polyester 3%	Satin	264	80x62
I	Cotton 100%	Twill	223	124x60
J	Cotton 98% Polyester 2%	Twill	215	72x61
K	Cotton 100%	Plain	143	136x88
L	Rayon 70% Polyester 30%	Plain	145	108x63
M	Cotton 95% Polyester 5%	Plain	221	80x56
N	Cotton 13% Polyester 87%	Plain	210	105x60
O	Cotton 45% Polyester 55%	Plain	146	80x60

The samples were laundered by following AATCC Monograph M6 [19]. A total of 20 laundering cycles were given to each of the collected sample and after an interval of five launderings, these materials were evaluated for the tensile strength by following Strip method ISO-13934-1 [20]. The specimen with specific dimensions was extended to measure its tensile strength, until it breaks.

Before evaluation, every sample was brought into moisture equilibrium under a standard atmosphere for accurate readings by following ASTM D1776 test procedure [21]. Five specimens were cut in each warp and weft directions with the dimensions of 200mm x 50mm (without fringes). It was ensured that no specimen was cut from within 150 mm of either edges of the collected sample. Warp specimen having similar ends and the weft specimen having similar picks were not considered for testing.

The specimens were mounted in a slack, (initially with a pre-tension of approximately zero) force in Newton. Each specimen was clamped in a vertical direction and was aligned in such a manner that its longitudinal center line passed through the center of the jaws. Then force was applied by moving the clamps. When clamps were put in an action, the specimen was extended to its point of rupture. The electronic device recorded maximum applied force for each of the five specimens in warp and weft directions. This force was recorded in Newton.

III. RESULTS AND DISCUSSION

Protective clothing must be evaluated for its tensile strength in order to protect the wearer from certain hazards in the environment [22]. Strength is considered as the most important criteria in determining the performance of clothing materials [23-24].

TABLE II TENSILE STRENGTH OF COLLECTED SAMPLES IN WARP DIRECTION

Mean value (warp direction) in Newton										
Sample	0-Wash		5-Wash		10-Wash		15-Wash		20-Wash	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
A	1109.1	0.31	1108.88	0.56	1088.7	0.65	1062.42	0.54	1036.96	0.68
B	850.28	0.45	841.14	0.52	802	0.54	780.06	0.65	726.16	0.54
C	816.06	0.32	803.24	0.65	779.02	0.58	755.68	0.23	730.5	0.58
D	954.82	0.35	937.6	0.45	906.8	0.32	884.42	0.25	857.96	0.65
E	1079.42	0.54	1057	0.35	1019.16	0.25	993.76	0.65	975.84	0.78
F	1188.66	0.56	1179.88	0.48	1150.16	0.55	1126.4	0.54	1096.24	0.43
G	603.24	0.45	602.9	0.85	582.5	0.41	546.96	0.58	531.26	0.26
H	1243.86	0.54	1238.36	0.57	1198.4	0.45	1166.22	0.45	1143.74	0.51
I	949.4	0.65	938.1	0.65	903.04	0.67	876.2	0.65	842.06	0.56
J	982.28	0.35	960.76	0.25	912.44	0.47	877.74	0.45	865.2	0.58
K	597.84	0.23	588.48	0.35	547.12	0.35	513.38	0.28	483.56	0.43
L	653.52	0.51	637.28	0.22	604.28	0.69	577.74	0.48	521.32	0.51
M	500.56	0.65	488.94	084	462.68	0.58	426.4	0.58	398.84	0.49
N	713.42	0.52	698.84	0.78	687.26	0.51	664.98	0.54	647	0.24
O	519.76	0.32	481.72	0.54	483.9	0.34	450.32	0.55	399.26	0.39

It was observed through the experiments that all tested specimens lost their strength with increasing washing intervals in their warp direction (Table 2). The stress strain curve in clothing materials is characterized by the presence of the crimp and open structure of woven fabrics. Crimped yarns become straightened under tension at low stress, that results in the low tensile stiffness at the initial point. De-crimping happens and results in the improvement of inter fiber friction, at high stress. It assists in adequate orientation of fibers and forms a consolidated fabric structure [8]. The specimens were not able to resist the same pressure at each interval, as they lost their strength with an increasing number of washes.

TABLE III
TESTS OF WITHIN-SUBJECTS CONTRASTS FOR TENSILE STRENGTH IN WARP DIRECTION

Source	Different Washes	Type III Sum of Squares	Df	Mean Square	F	p-value
Different washes	Linear	100004.991	1	100004.991	439.763	0.000

The p-value (Table 3) is found as 0.000 that explains a statistical difference between tensile strength of all samples in their warp direction after various washing intervals. The tested specimens lost their strength after each washing interval. Literature shows that there are several factors that depend on the tensile and tear strength of fabrics such as fiber type, yarn type, fabric geometry, amount and type of twist, interlacing pattern, warp and weft density and finishes applied over the structure [25-27].

TABLE IV:
TENSILE STRENGTH OF COLLECTED SAMPLES IN WEFT DIRECTION

	Mean value (weft direction) in Newton									
Sample	0-Wash		5-Wash		10-Wash		15-Wash		20-Wash	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
A	879.12	0.65	860.56	0.45	845.1	0.52	816.9	065	786.7	0.58
B	659.42	0.56	640.26	0.36	615.26	0.25	591.54	0.48	567.78	0.49
C	626.72	0.85	608.72	0.56	593.58	0.35	531.86	0.29	541.64	0.65
D	465.72	0.65	449.82	0.75	419.66	0.36	397.64	0.65	369.66	0.52
E	879.44	0.42	861.96	0.24	836.24	0.63	803.32	0.84	758.14	0.64
F	984.68	0.35	967.56	0.35	942.42	0.51	926.98	0.54	894.66	0.55
G	491.26	0.34	449.94	0.51	426.66	0.25	398.74	0.65	384.52	0.46
H	595.28	0.51	571.58	0.45	546.4	0.54	515.82	0.51	488.24	0.57
I	690.28	0.24	659.48	0.44	636.1	0.52	602.54	0.35	579.92	0.19
J	538.88	0.23	520.3	0.65	497.5	0.45	467.98	0.39	446.02	0.25
K	498.32	0.51	483.76	0.35	463.28	0.51	430.06	0.74	405.52	0.48
L	523.44	0.56	503.98	0.34	488.06	0.55	475.78	0.56	449.24	0.35
M	419.06	0.43	413.08	0.51	395.3	0.46	364.22	0.58	337.3	0.57
N	433.38	0.42	409.02	0.44	381.14	0.57	348.72	0.61	330.58	0.65
O	460	0.21	439.62	0.51	419.82	0.59	393.74	0.14	367.98	0.34

It can be clearly seen from the results that the warp direction of each specimen has greater tensile strength at every interval as compared to the weft direction. This fact is also supported by [23] that warp yarns are stronger as compared to the weft yarns, because there is a large number of yarns present in this direction that helps to create a base structure of fabrics. Moreover, these yarns are also given more twist per inch than weft yarns, as they need to be kept under tension during the interlacing process.

It was also observed that tested specimens lost their strength in direction as well with increasing laundering intervals (Table 4). It was concluded that various weaving patterns have a strong relationship with tensile strength of finished fabric. Long floats break the fiber more easily such as in stain and sateen weave types whereas, more interlacing such as in plain structure help to make a compact fabric and able to offer high resistance against tensile loadings in textile materials [28].Low tensile and tear strength demanded by the fabric manufacturers ensures that they are using a low quality of fibers and yarns in making of clothing products [22, 25].

TABLE V:
TESTS OF WITHIN-SUBJECTS CONTRASTS FOR TENSILE STRENGTH IN WEFT DIRECTION

Source	Different_ Washes	Type III Sum of Squares	Df	Mean Square	F	p-value
Different washes	Linear	88719.360	1	88719.360	976.984	0.000

The p-value was calculated as 0.000 (Table 5) that describes a significant statistical difference in tensile strength of tested samples for their weft direction after various washing intervals. These samples lost their tensile strength with an increasing number of washing cycles and reduced their performance. The main reason of reduction in tensile strength of collected samples was a low quality of fibers used in manufacturing these materials, which made them unable to withstand laundering conditions. The lint was detached from the upper layer of fabrics with an increased number of washing cycles thus reduced their strength. This phenomenon was also highlighted by [29] that laundering reduces the mass of fabrics which make them weak in their tensile strength .

IV. CONCLUSION

The present study concludes that all the tested specimens failed to meet the international safety standard ISO 13934-1 for their tensile strength and even their behavior deteriorated with each washing cycle. Due to the poor quality of fibers used in their manufacturing as well as the absence of adequate coatings and lamination, tested samples were unable to resist laundering procedure. Findings of this study can serve as a helpful tool for textile manufacturers to revise and modify their construction specifications in making chemical protective clothing to ensure wearer's safety and protection. The regular laundering cycles may create variation in the strength of fabrics due to the swelling up of fibers due to mechanical agitation. The investigations presented here identifies the quality of collected samples used by various chemical industries. Examining the effect of laundering on durability of clothes is of special interest to the wearer and laundry agencies. Consumer requires that the material should be durable and do not lose its strength after wearing, rubbing or washing. Deterioration in the strength of fabric also reduces the economic benefit of clothes.

REFERENCES

[1] K. Mani, and V. Sivakkumar, "Chemical protective clothing", *Pakistan Textile Journal*, pp.40-43, 2011.
[2] Occupational Safety and Health Administration. *Personal protective equipment,* Technical Manual, 2003.
[3] "Personal protective equipment at work", June, 2016. [online]. Available: http://www.hse.gov.uk/pubns/indg174.pdf
[4] Aguwa, N. Emmanuel, U, Sussan. Arinze-Onyia, and A, Ndu. "Use of Personal Protective Equipment among Health Workers in a Tertiary Health Institution, South East Nigeria: Pre-Ebola Period." , 2016.
[5] L. Archana, and C. M.Paul, "A study on personal protective equipment use among health care providers, Tamil Nadu." *International Journal Of Community Medicine And Public Health* vol. 5, no.5, pp.1771-1774, 2018.
[6] M.J. Stellman, (2015, May). *"Encyclopaedia of occupational health and safety". [online] Available:* http://www.ilo.org/oshenc/part-iv/personal-protection/item/691
[7] S. Sawada, and Shin-ichi, "New development of research on personal protective equipment (PPE) for occupational safety and health." *Industrial health* vol.55, no. 6, pp. 471-472, 2017.
[8] J. Hu, *Structure and mechanics of woven fabrics*, Cambridge: Woodhead Publishing Limited, 2004
[9] J. R. Bassett, R. Postle, and N. Pan, (1999). "Experimental methods for measuring fabric mechanical properties: A review and analysis", . *Textile Research Journal*, vol. 69, no. 11, 1999
[10] *American Heritage Science Dictionary*. Houghton Mifflin Company: Boston, 2005
[11] C.M. Yi, "Effect of Washing on Tensile Strength of Denim Fabric". B.A Thesis, The Hong Kong Polytechnic University, 2011
[12] C.W. Smith, "An overview of protective clothing - markets, materials, needs", www.intexa.com/downloads/pcc.pdf, 1999.
[13] Madanhire and C. Mbohwa. *Mitigating environmental impact of petroleum lubricants,* Berlin: Springer, 2016.
[14] T. Benjamin, B.Yu and B. Fei, "Advances in flame retardant poly (lactic acid)." *Polymers*, vol.10, no.8, 2018
[15] E. Hilenberg, E. Taskin and A. Ehrmann. "Increased acid-resistance of lab-coats by hydrophobic finishing", *International Journal of Clothing Science and Technology,* Vol. 30, no.6 pp. 784-789, 2018.
[16] F. Hosseinali, "*Investigation on the Tensile Properties of Individual Cotton (Gossypium hirsutum L.) Fibers".* Master's thesis, Texas tech university, 2012.
[17] R. Kovar, " Anisotropy in woven fabric stress and

elongation at break", in Woven fabric engineering, Croatia, Sciyo, 2010, pp.1-24.

[18] L.W. Winnie, "*A study on fabric anisotropy".* Doctoral Dissertation. The Hong Kong Polytechnic University, 2001.

[19] *Standardization of home laundry test conditions,* AATCC Monograph M6, 2013.

[20] *Determination of maximum force and elongation at maximum force using the (strip method).* ISO 13934-1

[21] *Standard practice for conditioning and testing textiles,* ASTM D1776, 2015

[22] B. Witkowska, and I. Frydrych, (2005). "Protective clothing–test methods and criteria of tear resistance assessment", *International Journal of Clothing Science and Technology*, vol. 17, no. 3, pp. 242-252, 2005.

[23] W.J. Hearle, and E.W. Morton,. *Physical properties of textile fibres*, Manchester: Woodhead Pub

[24] S. Gordon, and L.Y. Hsieh, *Cotton: Science and Technology,* Cambridge: Woodhead publishing Limited, 2007, pp.3-34.

[25] A.Z. Malik, T. Hussain, H.M. Malik, H.M. Hussain, and A. F. Arain, "Development of Models to Predict Tensile Strength of Cotton Woven Fabrics", *Journal of engineered fibers and fabrics*, vol. 6, no. 4, pp. 46-53, 2011.

[26] H. Gabrijelcic, E. Cernosa, and K. Dimitrovski, "Influence of Weave and Weft Characteristics on Tensile Properties of Fabrics", *Fibers and textiles in Eastern Europe*, vol. 16, no. 2, pp. 45-51, 2008.

[27] R. Chattopadhyay, "Design of apparel fabrics: Role of fiber, yarn and fabric parameters on its functional attributes", *Journal of Textile Engineering,* vol. 54, pp. 179-190, 2008.

[28] A.Z. Malik, T. Hussain, H.M. Malik, A. Tanwari, "Selection of Yarn for the Predefined Tensile Strength of Cotton Woven Fabrics. *Fibers and polymers,* vol. 12, no. 2, pp. 281-287, 2008.

[29] F. Kishwar, (2000). "Investigations related to hydrodynamic characteristics and safety profile of surgical gowns.*"* Doctoral dissertation, University of Punjab, Pakistan, 2013.