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Fabrics deterioration under the influence of environmental conditions at an urban industrial site in Egypt

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ABSTRACT

The present study dealt with evaluating the degradation produced to four fabricated polymers after one year of continuous direct exposure to the environmental conditions prevailing at an industrial urban site in, Helwan city, Egypt. The produced damage in the mechanical properties was assessed by evaluating the loss in tensile strength, elongation percent, weight, thickness, drap and stiffness values. Also, the changes in the pH, number of carboxyl end group values and surface morphology of examined samples are studied. The prevailing environmental conditions at exposure site are severe and contribute greatly to the deterioration occurring to the examined fabrics. Also that site is characterized by the presence of many industrial factories as: iron and steel, coal, cement, cars, textiles, metallurgy and some other factories that cause considerable environmental pollution. Nevertheless, summer time especially august was the most effective period and recorded the maximum changes and damage to the examined fabrics.

Introduction

Several authors have reported the photodegradation of textile fabrics produced by exposure to sunlight.[1-12] The feature of weather most responsible for photodegradation are light particularly of near UV of the range (290-315 nm),[3, 9, 10, 13, 14] moisture in the liquid or vapor form, temperature, oxygen, ozone and pollutants. Weathering is known to result in progressive molecular chain scission at the exposed surface, and a serious reduction in mechanical properties. In the case of fabrics the action is especially severe because of the high surface to volume ratio. Physical changes may occur, loss in tensile strength, elongation, bursting strength, stiffness, color, surface and molecular weight, besides changing in the pH values and carboxyl content groups[1-12] Weathering tests have come under suspicion, since at a constant level of total incident radiation, degradation seems to proceed faster in summer than in winter due to the seasonal fluctuations occurring in the UV radiation which were attributed to the cyclic seasonal variation of ozone formed from atmospheric oxygen by photochemical processes.[3] Thus, UV region is the most energetic radiation from the sun and therefore can cause the most damage to fabrics.[14] Indeed it was proved that UV radiation of the spectrum is more damaging than visible or IR ones,[3, 4, 9, 10, 13,14] and fig (1) shows the energy of the electromagnetic radiation wave length in(nm) and frequency in cm^{-1} and the corresponding energy in($kcal.\ mol^{-1}$)[9].

This study shows the degradation produced to four different fabrics after direct monthly exposure for one year at an industrial site in Egypt. The results showed that the environmental conditions at that site are severe and caused considerable damage to the examined fabrics. Summer time exposure was more damaging than the other seasons. Monthly losses in all studied properties showed a cyclic trend similar to the monthly changes of incident solar energy and UV radiation values. Better correlations exist between the losses in strength and elongation values with the UV radiation than those with the incident solar energy.

Experimental

Fabric

Unfinished fabric samples were selected for this study , two cotton samples of different counts and densities namely lino and drill together with plain polyester and nylon-6 fabrics. The nominal weights of these samples were: 90,480,187 and 160 gm^{-2} respectively.

Exposure

Unprotected outdoor exposure was applied according to the standard method. [3-5, 12] Starting on January (2011) and till the end of December. One set of all examined samples was removed monthly and another set was removed at the end of the year.

Temperature and Relative Humidity (R.H.)

The daily average maximum of each month for both temperature and R.H.values were recorded , and hence , the monthy averages were obtained.

Sunny Hours , Incident Solar Energy (ISE) and The Accompaenied UV Radiation

The number of sunny hours per month for the whole year together with the ISE were recorded and the accompaenied UV radiation content at (290-315 nm) were evaluated[3] and the average values were calculated for each exposure month. The weathering data were taken from the nearest meteorological station to the exposure site.

Physical , Mechanical and Chemical Measurements.

These measurements were performed on the examined fabric samples before and after exposure periods according to the standard methods.

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a. Weight (gm^{-2}) [15,16], thickness [16,17], drap [16,18], stiffness[16,18]
b. Tensile strenth and elongation[16,19]
c. The pH and carboxyl group's values[20]
d. Surface morphology [12]

Results and discussion

Environmental conditions

The monthly Incident Solar Radiation Energy ISE evaluated according to World Radiation Reference in (MJm^{-2}) are shown in Figure (2) together with the year months, curve (a) where a cyclic variation is observed having a maximum in August and a minimum in Janurary and December. Also,the monthly levels of UV radiation in ($mW\ min^{-1}cm^{-2}$) at the range (290-315 nm) were estimated from the ISE values and are represented in Figure (2) curve (b) where a similar curve is obtained with miximum in summer time and minimum in winter time. Also a cyclic variartions with a maximum in August were obtained when the mean daily maximum temperatures, and relative humidity per month were represented against the months of the year Fig.(3). Also, when the number of the daily sun hours per month were represented against the same parameters as shown in Fig.(4)

Considering the results of Figures (2-4), it was concluded that Helwan city is characterized by severe environmental conditions, especially in summer time, leading to high temperature values and relative humidity values, long sunny hours. Also, the site is subjected to high levels of ISE and UV radiation values when compared to any other place in the world. The average maximum temperature through April - October ranged (31.4 - 35°C), and the total monthly sun hours during the same period ranged (258 - 372 hours), whilst the RH ranged (77 - 87%).

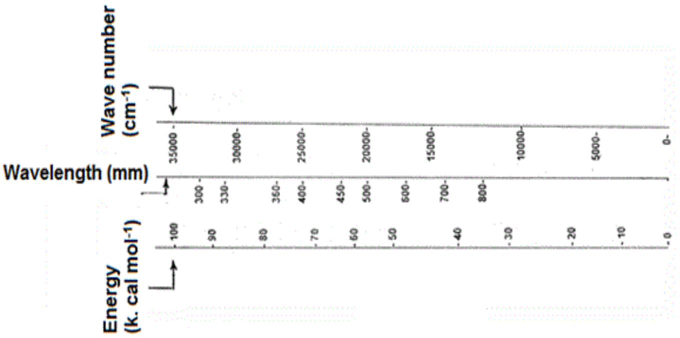

Figure 1. Wavelength of the electromagnetic radiation (nm) and wave number (cm^{-1}) and their corresponding energy (kcal/mol)

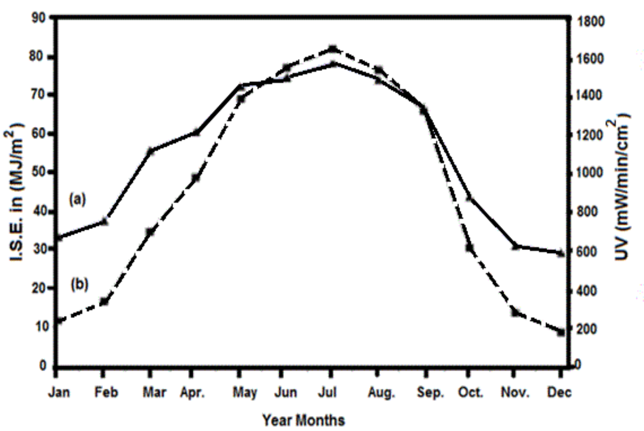

Figure 2. Shows monthly the I.S.E, UV radiation values of the whole year

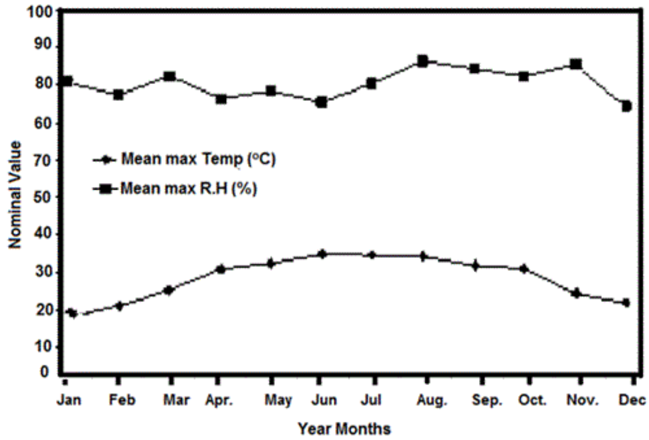

Figure 3. Shows the variation of the monthly mean max temp (°C), and relative humidity of the whole year months.

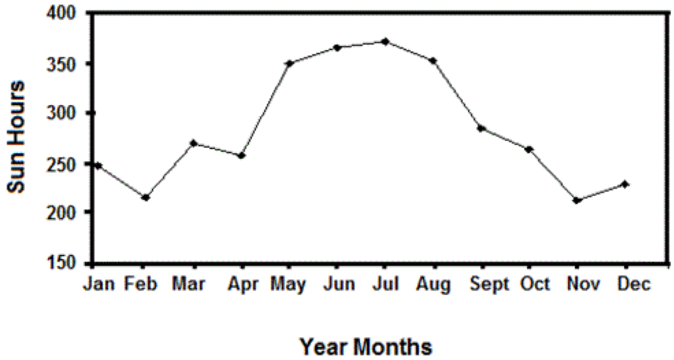

Figure 4. Shows the variation of the monthly sunny hours of the whole year months

The monthly ISE and UV radiation during May - August ranging (72202 - 78176 MJm^{-2}), (1278 - 1634 $mWmin^{-1}cm^{-2}$) respectively. These environmental conditions together with the surrounding pollution produced by the industrial activities contributed considerably to the deterioration of the examined exposed fabrics.

Effect of environmental conditions on physical, mechanical and chemical properties of the examined fabric samples

Photodegradation of the examined fabrics was assessed by following the change in their mechanical, physical and chemical properties. The produced deterioration arising from exposure to the prevailing environmental conditions i.e. weathering is represented as variation of the samples tensile strengths (T.S), elongation percentage (E%), weight per m^2, thickness, drap and stiffness values . Also changes of: the surface morphology, the pH values and carboxyl end groups.

When plotting the values of the tensile strength values of the four examined fabric samples and also their elongation percentage values before and after the monthly exposure periods of the whole year, Figures (5, 6) were obtained. These figures show that the values of the(TS) and (E%) were decreased gradually as the monthly exposure time was proceeded showing maximum decrease in August , then the decrease was lowered till the rest of the year recording a minimum values in December .The obtained results showed that the fabric samples had lost a considerable amounts of their strength by such exposure .The monthly losses in strength ranged (45-51) whilst in elongation % (33.7-57).The obtained curves showed similar cyclic variations as those of the environmental condition curves of Figure (2) confirming the fact that the ISE and UV radiation contribute greatly to the fabrics degradation.

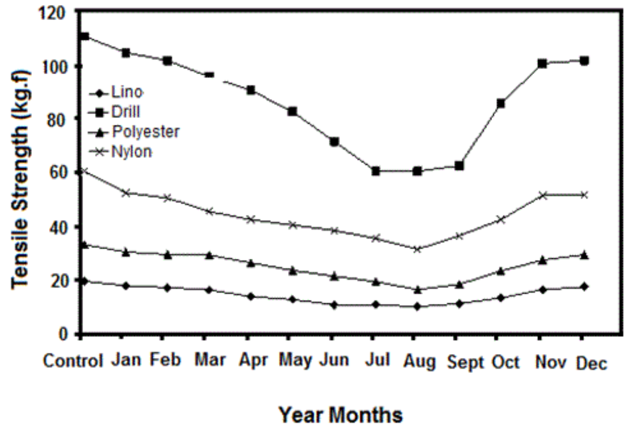

Figure 5. Shows the variation of the tensile strength values of the examined fabrics against exposure year months.

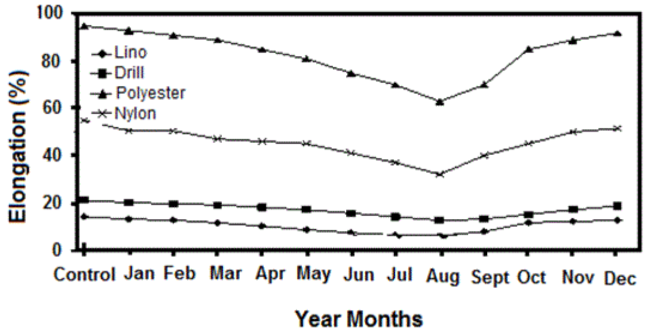

Figure 6. Shows the variation of the elongation (%) values of the examined fabrics against exposure year months

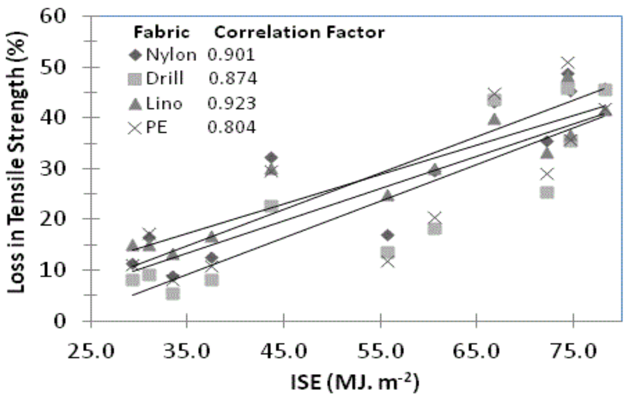

Figure 7 .Relation between losses in tensile strength (%) vs. the monthly ISE values for the four examined fabrics

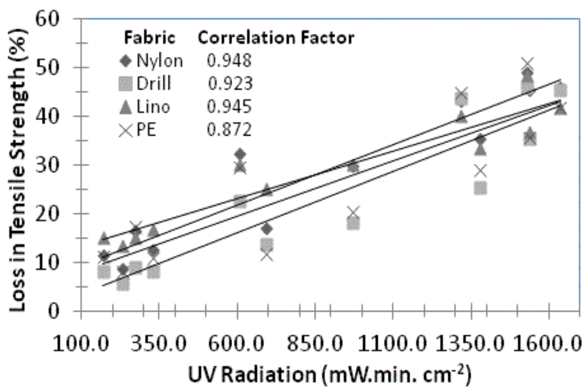

Figure 8. Relation between losses in tensile strength (%) vs. the monthly UV radiation values for the four examined fabrics.

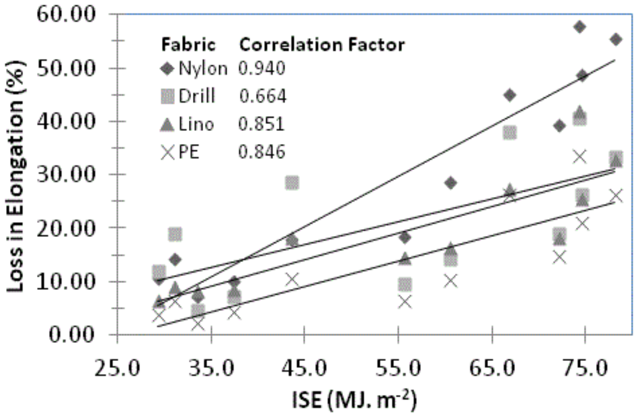

Figure 9. Relation between loss in Elongation (%) vs. the monthly ISE values for the four examined fabrics

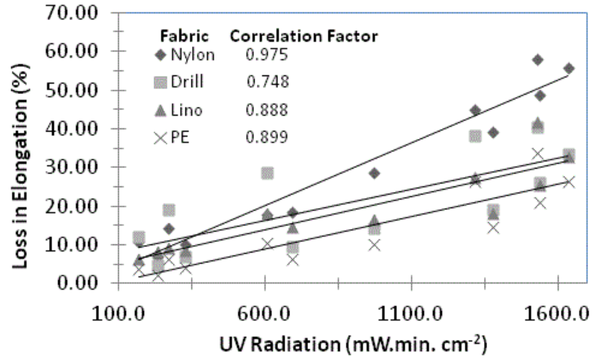

Figure 10. Relation between losses in Elongation (%) vs. the monthly UV radiation values for the four examined fabrics.

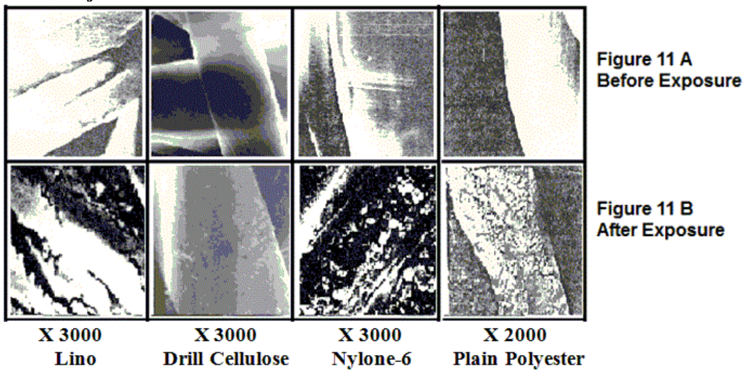

Figure 11. Shows the the SEM photographs of the four examined fabrics (A) before and (B) after one year continuous exposure to the environmental conditions

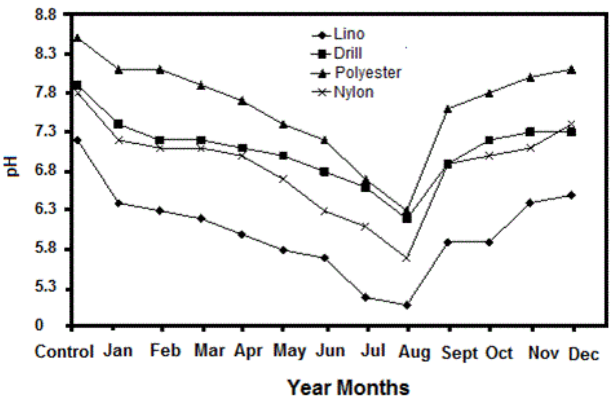

Figure 12. Shows the variation of the pH values of the examined fabrics against exposure year months

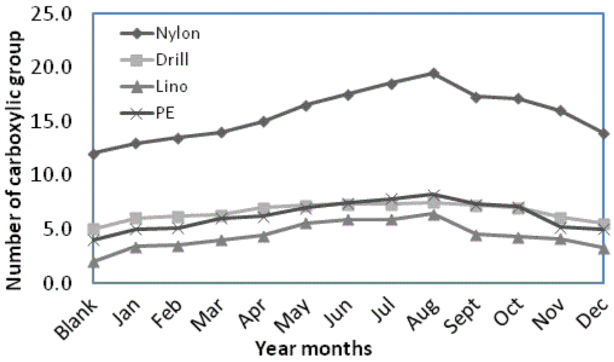

Figure 13. Effect of exposure time on the number of carboxylic group on the examined fabric

When the percentage loss values in the (TS) of the four examined fabrics were plotted against the monthly ISE and UV values, Figures (7 & 8) were obtained , while Figures (9 & 10) showed the percentage loss in (E%) values against the same parameters. These curves indicate that there exists a direct relation between the percentage loss in the (TS) and / or the (E%) of the examined fabrics and the absorbed amounts of (ISE) and(UV radiation. They also showed stronger correlation exists with the UV radiation values than those with the (ISE). The correlation factors of loss in strengths of the four examined fabrics with ISE and UV ranged (82-92) and (88-95) respectively while those of the loss in (E %) with the same parameters ranged (66-94) and (75-97) respectively.

Considering the variation of the weight (gm^{-2}) and thickness values produced to the examined fabric samples by the monthly exposure to the environmental conditions and presented in Tables (1 and 2) , it was concluded that the samples weight and thickness were slightly affected by such exposure . Small gradual decrease was observed reaching maximum values during summer months (June - August), followed by an appreciable decrease till the end of the exposure times. Cellulosic Lino fabric representing the finest samples of the examined fabrics, showed (15%) loss values for both weight and thickness after August exposure time, while the other samples losses did not exceed (4%)

The drap values of the examined fabrics of (Table 3) were increased gradually showing a maximum in July followed by a continuous small increase as the exposure was proceeded. These findings indicate that draping property of the fabrics had decreased in spite of the decrement of the sample's weight which calls to draping property improvement.

The results of Table (4) showed that the sample's stiffness were increased gradually reaching a maximum in August then decreased as the exposure was extended. The samples became more stiff and harder after exposure to the environmental conditions explaining the decrease of draping property and also the pronounced loss of tensile strength and elongation values produced by exposure to environmental conditions.

SEM photographs presented in Figures (11A&B) are for the examined fabric samples before and after one year of continuous exposure to the environmental conditions. These Figures show clearly the produced damage occurring to the fibers surface arising from such exposure. The fabrics fibers became more obscure and their surface roughness were increased and a number of depressions were observed. Lino, nylon, and polyester samples were seriously affected, while cellulosic drill samples representing courser cotton fibers were less affected .

Concerning figure (12), it shows the variation of the pH values of the aqueous extract of each fabric samples before and after each exposure month of the whole year. It is clear that the pH values decrease gradually as the exposure was preceded reaching maximum decrement through July and August, then the pH values increased gradually as the exposure was extended. The acidity of the fabric samples was increased at different rates depending on the structural nature of the fabric and the exposure time and followed the order Lino >Nylon.>Polyester>Drill. The apparent decrease in pH , is possibly because of the polluted surrounding atmosphere at that urban industrial site of Helwan city which contains considerable amounts of different types of gases produced by many industries located there e.g.CO_2, CO, NO, NO_2, NH_3, H_2S, Cl_2.

Regarding the carboxyl end groups, the observed increase of their values was shown in fig. (13).These curves assured that the examined fabric samples were affected by such. Exposure to the environmental conditions and that the change during summer time was more pronounced especially during July and August where maximum deterioration was observed. Comparing the fabric performance, Lino samples recorded the highest increase of carboxyl end groups followed by Polyester then Nylon and finally Drill. The increase of both the carboxyl groups and the acidity of the examined fabrics indicate that chemical degradation had occurred, and that the change was affected by the exposure time and the fabric nature. These observed changes with respect to the monthly exposure time, followed the same cyclic trend as those of the other properties same trend as those of the other properties.

Conclusions

The observed degradation in all examined physical, mechanical and chemical properties of the fabrics under test may be attributed to the severe environmental conditions prevailing at Helwan site, which were expressed as high temperature and (R.H) values, long sunny day hours , high values of ISE and near UV radiation. Besides, the pronounced pollution of the atmosphere and the presence of huge amounts of pollutant gases resulting from the increased industrial activities. Also, may be due to the great amount of fuel usage either by domestic or industrial purposes, and the pronounced increase of the population density at that site.

The obtained results indicate that the decrease in all examined properties with the monthly exposure times showed cyclic curves similar to the change of the monthly ISE and UV radiation values. Stronger correlation exists between the losses in strength and / or (E %) values with the UV radiation than those with the ISE, indicating that UV radiation is the predominant factor affecting textile photodegradation and may be taken as an exposure index. Moreover, the examined fabrics showed changes in their surface morphology after one year of continues exposure, and cyclic increment of their acidity and carboxyl group values with the monthly exposure to the environmental conditions at Helwan site.

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Table 1: The weight variation ($g.m^{-2}$) of the examined fabrics against the exposure months

Exposure Months	Lino Cellulose	Drill Cellulose	Plain Polyester	Plain Nylon-6
Control	90.00	480.0	186.0	160.0
Jan	80.96	478.3	181.6	159.3
Feb	80.51	467.5	180.9	158.4
Mar	80.16	460.6	179.3	158.2
April	80.40	460.6	179.0	158.0
May	79.80	450.9	178.2	157.4
Jun	79.30	450.9	178.1	154.3
July	76.40	450.9	176.7	151.8
Aug	77.10	460.0	179.0	156.9
Sep	80.20	470.4	179.2	157.2
Oct	80.50	472.3	179.6	158.4
Nov	80.70	477.2	180.1	159.0
Dec	80.90	478.9	180.4	159.1

Table 2: The thickness variation (mm $x10^2$) of the examined fabrics against the exposure months

Exposure Months	Lino Cellulose	Drill Cellulose	Plain Polyester	Plain Nylon-6
Control	48.2	100.8	33.4	50.1
Jan	44.2	100.0	33.2	48.8
Feb	43.8	99.6	32.8	48.7
Mar	41.8	99.6	32.8	48.5
April	40.9	99.4	32.3	48.1
May	40.4	99.2	32.3	47.9
Jun	40.2	99.0	32.0	47.7
July	40.2	99.0	32.0	47.7
Aug	40.3	99.3	32.4	47.9
Sep	40.9	99.4	32.4	48.5
Oct	41.1	99.4	32.6	48.5
Nov	43.1	99.9	32.6	48.7
Dec	43.8	99.9	32.8	48.7

Table 3: The drap variation (mm) of the examined fabrics against the exposure months

Exposure Months	Lino Cellulose	Drill Cellulose	Plain Polyester	Plain Nylon-6
Control	12.1	60.6	16.8	13.5
Jan	13.1	65.2	18.0	14.2
Feb	14.1	66.1	19.6	14.7
Mar	14.4	66.2	19.6	15.0
April	14.6	66.2	20.7	15.1
May	14.7	67.3	21.2	15.1
Jun	14.9	68.0	21.3	15.1
July	14.9	68.3	20.9	15.1
Aug	14.8	67.6	20.5	15.1
Sep	14.6	67.3	19.9	15.0
Oct	14.2	66.9	19.8	15.0
Nov	13.9	65.6	19.6	14.9
Dec	13.7	64.4	18.9	14.3

Table 4: The stiffness variation (g. cm^{-1}) of the examined fabrics against the exposure months

Exposure Months	Lino Cellulose	Drill Cellulose	Plain Polyester	Plain Nylon-6
Control	0.0231	1.27	0.132	0.028
Jan	0.0291	1.57	0.159	0.032
Feb	0.0391	1.58	0.204	0.036
Mar	0.0337	1.59	0.202	0.038
April	0.0364	1.59	0.239	0.039
May	0.0364	1.63	0.256	0.039
Jun	0.0372	1.68	0.259	0.038
July	0.0364	1.70	0.241	0.037
Aug	0.0364	1.57	0.229	0.038
Sep	0.0364	1.49	0.212	0.038
Oct	0.0328	1.42	0.207	0.038
Nov	0.0310	1.36	0.203	0.037
Dec	0.0301	1.28	0.182	0.034

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