A Green Approach: Comparative Study of Virgin and Recycled Polyester for Textile Application

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Abstract- Polyester is made from petroleum resource that creates damaging environmental impacts during the manufacturing process. It is non-biodegradable in nature & takes 35-42 years to decompose. Thus, management of PET Waste becomes an important social issue. The recycled polyester was prepared from PET Waste bottles. The object was to study the chemical as well as physical properties of the Virgin & Recycled polyester fabric. The virgin & Recycled polyester yarn with 75 Denier & 150 Denier was procured from Polygenta industries, India & Reliance Industries, India respectively. The fabric was produced on Sample Weaving Machine. The fabrics were dyed with Coralene Yellow 4G disperse dyes. The various color aspects like K/S, fastness on Virgin & Recycled polyester fabric were measured by using computer color matching system. The result showed that Disperse dyed recycled polyester fabric made from both denier showed lesser K/S values compared to virgin from 0.5% to 4% shade. At 4 % shade the difference in K/S value is not significant. Further, as percentage shade increases above 4%, improvement in dye uptake was observed for recycled sample.

Keywords - Virgin polyester, Recycled polyester, Polyester dyeing, K/S, Green chemistry.

1. INTRODUCTION

Polyester is made from a non-renewable resource that creates damaging environmental impacts during the extraction process. It is non-biodegradable in nature and takes almost 35 to 42 years to decompose. (Adanur, 1995) Thus management of PET waste has become an important social issue. The worldwide consumption of the bottle grade PET was 15 million metric tons which represents almost 8% of total demand of standard plastic in 2007. The recycled polyester is accounted for 8% overall PET production and it is said to increase by 10% every year.(Comperl;1993, East; 2004).Recycling, as an important principle of green chemistry is the most promising approach to reduce the solid waste. The world's most recyclable polymer is polyester. (George; 2004, Sharma; 1995) Some of the products in which recycled polyester is used are fibers, films, foam, sheeting, food and non-food contact bottles. It was claimed that in 1994 over 500 million plastic containers were converted into 45 million pounds of polyester fibers for carpet and home furnishing sector. (Bassett; 1992, Leian; 2012, Reese; 2003). Many research papers reviews the method of recycling post-consumer waste PET bottles to form textile fibers. The process involved in complete recycling consists of chemical as well as mechanical methods. In this paper an attempt has been made to study the difference between recycled polyester and virgin polyester of the same denier which concludes sustainability of recycled polyester as an alternative to the virgin polyester. The various physical tests like crease recovery angle, bending length, abrasion and single yarn strength were carried out. Dyeing of both recycled polyester and virgin polyester was also carried out with similar dye & dyeing conditions. Colour strength & fastness properties were evaluated for analyzing the difference in the dyeing properties.

2. MATERIALS AND METHODS

With courtesy, 75 Denier & 150 Denier texturized twist less POY recycled polyester made available by Polygenta industries, India & virgin polyester from Reliance Industries, India was taken for study. Weaving was then carried out on sample weaving machine with EPI 84 and PPI 76. Soaping treatment followed by Heat setting at 190^0C for 30 sec. was carried out for both the samples. Samples were dyed by using HTHP method with Coralene Yellow 4G 200% dye of Colourtex Industries. MATHIS Labomat Model No. CH-8156 was used and dyeing was carried out from 0.5 % shade to saturation concentration of the dye on both the fibres. The temperature used was 130ºC with MLR 1:20 and dyeing time of 60 minutes. The K/S values were found by using Macbeth spectrophotometer at integrated wavelength using Colorscan software.

3. TESTING & ANALYSIS

3.1 Tenacity and elongation

Tenacity and elongation of both virgin and recycled polyester fibres were tested on Instron Tester using ISO3675 standard test method with gauge length 50cm. 20 readings were taken and mean and CV% was found out.

3.2 Moisture Regain

The moisture regain of the virgin & recycled polyester fabric was tested by using ASTM D2495 standard test method.

3.3 Bending Length
The bending length of fabric made from virgin and recycle polyester fibres were tested by using standard test method ASTMD5732.

3.4 Crease Recovery Angle
The crease recovery angle of fabric made from virgin and recycle polyester fibres were tested by using standard test method ISO4681 test method. This test was conducted for warp and weft direction.

3.5 Abrasion Resistance
Abrasion resistance of fabric made from virgin and recycle polyester fibres were tested by using standard test method ASTMD4157.

3.6 Colour strength by reflectance
The dyed samples were evaluated for the depth of colour by reflectance method using 10 degree observer. K/S values of dyed virgin as well as recycled fabric were measured using Macbeth spectrophotometer at integrated wavelength using Colorscan software.

3.7 Washing Fastness
Wash fastness test was carried out using ISO 105 CO4 test method. The ratings were given using Macbeth spectrophotometer.

3.8 Rubbing fastness
The rubbing fastness test was carried out for comparative study. Dry as well as wet rubbing was tested for both the samples with 10 cycles. The rating was given with the help of Macbeth Spectrophotometer with colourscan system by AATCC8:2005 staining method.

3.9 Light Fastness
Light fastness was carried out on Digi Light xenon arc light fastness tester. The test method used was ASTM D 4303. Exposure time was 48 hours.

3.10 Sublimation Fastness
The sublimation fastness test was carried out using ISO 105-PO1 standard test method. Temperature 170ºC ,190ºC, 210ºC was taken and the time of contact was 45 seconds. The ratings were given using Macbeth spectrophotometer.

4.0 RESULTS & DISCUSSION

Table I: Elongation & Tenacity for 150 Denier Virgin & Recycled Polyester Fibre

	Elongation (%)		**Tenacity(gmf/tex)**	
	Virgin	Recycled	Virgin	Recycled
Mean	12.92	10.26	23.55	20.24
C.V.%	26.75	33.10	23.02	29.13

Table II: Elongation & Tenacity for 75 Denier Virgin & Recycled Polyester Fibre

	Elongation (%)		**Tenacity(gmf/tex)**	
	Virgin	Recycled	Virgin	Recycled
Mean	10.81	9.14	34.32	32.08
C.V.%	10.28	9.17	6.58	10.68

Table III: K/S of virgin & recycled polyester fabric (150 denier) dyed with Coralene Yellow 4G 200% dye

Sample	% Shade	K/S	RFL
Virgin	0.5	4.6	6.355
Recycled		3.2	8.495
Virgin	1	7.2	4.13
Recycled		5.6	5.165
Virgin	2	9.2	3.405
Recycled		8.4	3.625
Virgin	3	9.89	3.315
Recycled		9.87	3.265
Virgin	4	12.0	2.65
Recycled		11.9	2.83
Virgin	5	11.8	2.815
Recycled		12.2	2.7
Virgin	6	11.7	2.86
Recycled		12.7	2.62
Virgin	7	11.2	2.93
Recycled		12.7	2.66

Table IV: K/S of virgin & recycled polyester fabric (75 denier) dyed with Coralene Yellow 4G 200% dye

Sample	% Shade	K/S	RFL
Virgin	0.5	5.3	5.49
Recycled		4.6	6.26
Virgin	1	8.5	3.48
Recycled		7.3	4.005
Virgin	2	8.6	3.46
Recycled		8.3	3.75
Virgin	3	9.2	3.29
Recycled		9.15	2.95
Virgin	4	10.8	2.45
Recycled		10.7	2.53
Virgin	5	11.4	2.15
Recycled		11.8	2.1
Virgin	6	11.5	2.16
Recycled		12.4	2.0
Virgin	7	11.1	2.13
Recycled		12.6	2.0

The table III & IV depict K/S and reflectance values of vergin and recycled polyester dyed with Coralene Yellow 4G 200% on polyester fabric made from 150 and 75 denier respectively. It is observed that the recycled polyester fabric in both denier is lighter in colour strength as compared with virgin polyester from 0.5% to 4% shade concentration. In all the samples, K/S values

of recycled & virgin polyester show significant difference upto 4% concentration shade. After 4% concentration shade, the difference is marginal. The saturation concentration of Coralene Yellow 4G 200% dye is around 4%. The virgin polyester and recycled polyester show nearly similar diffusion of dye. It may be due to the same level at about 4% saturation concentration. This concludes that difference in K/S values of recycled and virgin polyester at 4 % shade is not significant. Below 4 % shade, K/S values of recycled sample are lesser and hence it gets dyed lighter than virgin polyester. This may be due to lower diffusion of disperse dye in case of recycled PET samples. Further, as % shade increases above 4%, improvement in dye uptake is observed for recycled polyester samples which may be due to increased amorphous region.

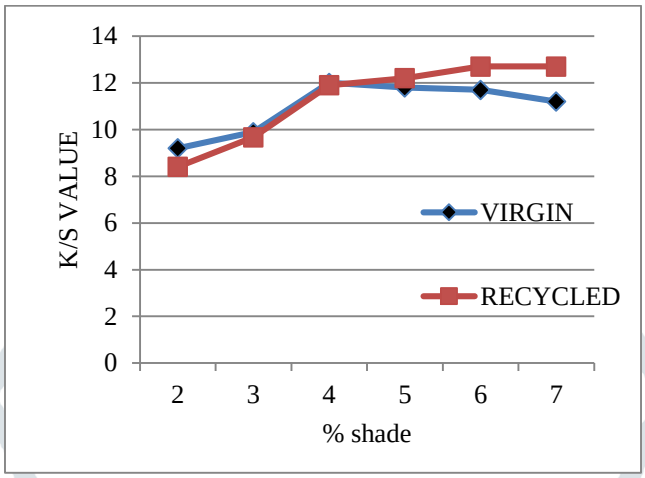

Fig. 1: Comparison of Saturation of Coralene Yellow 4G 200% Dye on Recycled and Virgin Polyester (150 denier)

From the graph (Fig. 1), of percentage shade against K/S values of virgin and recycled polyester it is observed that the K/S value for the virgin polyester increases up to 4% shade and dye gets saturated. Whereas in case of recycled polyester, saturation of the same dye takes place at 6% shade. The virgin polyester shows decreasing trend of K/S values after saturation concentration of 4%. The difference in the K/S values of both the polyesters above 4% concentration is significant. It shows that the dye uptake in case of recycled polyster is significantly higher than that of the virigin polyster.

4.1 Tenacity and elongation

The table I and II depict elongation and tenacity values of virgin and recycled polyester fibre made from 150 and 75 denier respectively. Table values show that tenacity of recycled polyester is less compared to virgin polyester fibre. This may be due to less crystallinity of recycled polyester compared to virgin polyester. The recycled polyester shows less elongation compared to virgin polyester due to non linear arrangement of polymeric chains. The coefficient of variation for elongation in case of 150 Denier recycled polyester is more than virgin polyester. This may be attributed towards the irregular molecular arrangement of cross linked polymeric chain.

4.2 Moisture Regain

The moisture regain of both the polyester is not significant. These values are 0.5 and 0.53 for virgin and recycled polyester respectively.

4.3 Bending Length

The bending length in case of virgin polyester is higher for both the deniers compared to recycled polyester fabric. This may be attributed to less chain stiffness caused by the recycling process.

4.4 Crease Recovery Angle

The crease recovery angle for 150 denier virgin was 112 & 110.6 for warp & weft respectively where as in case of recycled it was 91 for warp & 102.4 for weft. This may be attributed to the less elasticity caused due to annealing treatments during recycling process.

4.5 Abrasion Resistance

It was seen that recycled sample withstand up to 600 cycles whereas virgin polyester is only up to 400 cycles. The abrasion resistance of recycled polyester is more compared to virgin polyester of same denier. This may be due to the cross linking & non linear structure of the recycled polyester which resists abrasive forces better than virgin.

4.6 Sublimation Fastness

The sublimation fastness rating is 4-5 for recycled polyester whereas virgin polyester rating is 4. At 170ºC and 190ºC difference the rating is the same i.e. 4-5 whereas at 210ºC the variation in the fastness rating is observed. It may be due to excellent diffusion of dye in recycled polyester.

4.7 Washing Fastness

It is observed that the washing fastness of the recycled polyester fabric sample and virgin sample is almost the same i.e.4-5. This confirms that there is no adverse effect on dyeability of the recycled polyester even though there may be possibility of rearrangement of polymeric chains therein during recycling process. So the use of such a recylcled polyester as a substitute for virgin polyster is viable and feasible option for reducing the use of non-renewable feedstocks.

4.8 Rubbing fastness

The rating of both the virgin and recycled polyester in case of rubbing dry are the same i.e. 5 while the wet rubbing fastness is 4-5 in case of recycled polyester and it is 4 in case of the virgin polyester. This may be due to better dye transfer in case of the recycled polyester. It also supports that the process of recycle is synergetic one which leads to appropriate molecular rearrangement further helping migration of dye within fibre and subsequent dye fixation on to the recycled polyester fabric sample.

4.9 Light Fastness

The light fastness in case of virgin polyester is 6 while that of recycled polyester is 7. It also supports the viability and feasibility of using the recycled polyester as a substitute of the virgin polyester.

5. CONCLUSION

In this article an attempt has been made to compare the dyeing behavior of the samples dyed with Coralene Yellow 4G 200%. The results show the higher dye saturation values for recycled polyester as compared against the virgin polyester in both the deniers i.e. 75 and 150. As regards the green technology aspect of the work, it is worth mentioning that we have successfully employed few of the important principles of green chemistry.

After its use, the PET is being disposed off in the nature and it has great nuisance value in the form of environmental pollution due to its non-biodegradable property. There is global awareness for using the PET waste bottles for manufacturing textile polyester fibres. It is being considered as a strong alternative to reduce the use of virgin polyester for the textile application. In turns it reduces the use of non-renewable feedstocks from the nature. The research carried out by us reveals that, the green chemistry principles namely 'prevention of waste', 'recycling of the waste' and 'reducing the consumption of non-renewable feedstocks' from the nature are very well satisfied. The work carried out here is an effort towards sustainable development. The research work is an indicator of extension of the work of 'waste PET bottles recycle' on a large scale. It will help reducing the environmental pollution being caused as a result of dumping of the waste bottles into the environment.

The product of polyester fabric obtained through the source of recycled polyester fibre is a perfect substitute without any compromise in overall properties of the dyed polyester.

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