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Tensile Strength Assessment and Effluent Analysis of Multicoloured Textile Apparels Laundered in Anti-bleeding Solution

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Abstract

The investigation of the tensile strength of multicoloured textile apparel washed in water: anti-bleeding ratio is imperative to ascertain the durability of the textile material over a long period of time. In addition to this, the analysis of the effluent resulting from the process is vital to verify its environmental impacts. Swabs from the textile samples were analyzed to evaluate the tensile strength, elongation, % elongation and breaking load for when the samples were washed with the ratio in both soap and detergent with the textile sample swabs, A1, B1, C1 as reference samples. The effluent resulting for the treatment was analyzed by determination of various effluent parameters such as: pH, turbidity, temperature conductivity, total dissolved solid (TDS), total suspended solids (TSS) and the total solid (TS) in compliance with the Standard organization of Nigeria (SON). The tensile strength of the sample swabs shows that there was an increase in the tensile strength of the textile samples especially C2 and C3 having values of 245.32, 133.55 compare to the reference swabs C1, with a tensile strength of 72.37. However, other textile sample swabs exhibit little deviation in their tensile strength value from the reference samples (A1, B1, C1) for when washed with the formulation in soap and detergent solution. The investigation of their effluents shows that the untreated textile sample exhibit effluent parameter above the tolerable limit especially for sample A and B having TDS value of 136.00mg/L and 99.75mg/L respectively and other agencies. However, the treated textile samples have the value of their parameters below the tolerable limit as described by SON.

Keywords

Tensile Strength, Effluent Analysis, Fabric, Anti-bleeding

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1. Introduction

The textile industry is one of the largest and most complicated industrial chains in manufacturing industry [1-2]. The production of textile requires several stages of mechanical processing such as spinning, knitting, weaving, and garment production. These seems to be separate from wet treatment processes like sizing, desizing, scouring, bleaching, mercerizing, dyeing, printing and finishing operations, but there is a strong interrelation between dry processes and wet treatments [3-4].

Due to these treatment processes, there are certain factors that influences the loss in tensile strength properties of textile materials, especially the locally made 'Ankaras' and 'Kampalas'. Firstly, the wet treatment processes and different construction parameters that the fabric undergoes during various mechanical stages. This has an impact on the tensile strength of the textile material [5]. Another vital factor is the laundering process which textile apparel inevitably passes through during and after use. Research comparatively reveals

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that laundering is most damaging to textile apparel when compared to its usage or wear, causing fibre modification. This is due to the swelling capacity of the fibre in an alkaline detergent bath superimposed by mechanical agitation. These action leads to changes in fibre surface colour, textile hand, comfort and other parameters [6-7]. The tensile strength of textile material is the measurement of its resistance to applied external tensional force. It is mathematically expressed as force per unit area of unstrained specimen [8]. There are two approaches used in expressing this textile parameter. It can be expressed as tenacity i.e is the force per linear density of unstrained fabrics or as tensile stress which is force per unit cross sectional area of fabrics not under strain. On the other hand, tensile strain is the length deformation expressed by fabrics subjected to tensile force [8]. It is mathematically, expressed as extension per unit length of fabrics. Tensile strength is a vital mechanical property of fabrics in that, low strength properties shorten the useful life time as well disables the functionality of these products when under it undergoes tensional forces like pulling, rubbing, abrasion etc.

Apart from the tensile strength degradation, the attendant effluents realized from textile dyeing, finishing industry (especially the wet treatments) and domestic laundering operation of bleeding textiles with soaps and detergents has resulted into huge pollution problem to the environment [2, 9].

Literature findings on the physicochemical parameters of these effluents revealed that the temperature and pH is high, and extremely dangerous [10-11]. During laundry of most deeply coloured textile apparels, the colloidal matter present along with colours that bleeds out and oily scum increases the turbidity and gives the water a bad appearance and foul smell. It prevents the penetration of sunlight hence, prevents photosynthetic process when discharge to the water bodies [10]. The discharged effluents interfere with the oxygen transfer mechanism at air water interface depleting the value of the dissolved oxygen in water. This results to the depletion and death of most aquatic life. Furthermore, most of these effluents are indiscriminately discharged into the fields clogging the pores of the soil leading to loss of soil productivity. The texture of soil gets hardened and penetration of roots is prevented [11, 2].

Thus, it is imperative to evaluate the tensile property and various effluent parameters such as Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), Turbidity, Conductivity, pH, Temperature. This is because the long-term durability of the textile materials and eco-friendly nature of its attendant effluents must be established vis-à-vis its treatment with anti-bleeding solution studied by Adetuyi *et al.* [9]. The incorporation of anti-bleeding solution during laundry process forestalls the bleeding of the textile apparels as revealed by Adetuyi *et al*. [9]. Furthermore, the durability of these African made textile materials with respect to washing and its dye retention during laundry process offers good service in return for the cost of textile material purchased [12, 9].

Hence, this research aim at investigating the tensile strength properties of the textile apparels laundered with varying ratio of anti-bleeding to soap and detergent solution. And the environmental impact of the resulting effluent generated from these laundry processes when the anti-bleeding solution is incorporated during wash.

2. Materials and Method

2.1. Materials

Two yards (1.83 m) of 3 indigenous cellulosic printed fabrics (Ankaras) which are prone to bleeding and comprises of varying colour pattern (Figure 1), were obtained from Oja-Oba Akure, Nigeria. The chemicals used were $CaCl_2$, Na_2CO_3 and NaCl while the instrument used were analytical weighing balance, thermostatically controlled oven, amber bottle, pH meter, thermometer. Both (chemicals and Instruments) were obtained in the department of chemistry, Federal University of Technology, Akure, Nigeria. The Instron universal tensile testing machine was obtained from Obafemi Awolowo University Ile-Ife, Nigeria.

Figure 1. Textile samples.

2.2. Methods

2.2.1. Tensile Strength Properties of Laundered Fabrics

Three (3) sets of each sample were used for this analysis. Both treated (textile samples washed with varying ratio of anti-bleeding solution with soap and detergent solution respectively) and untreated samples (textile samples washed with soap and detergent solution) were cut into a length of 4 cm x 10 cm (2.8 g + 0.5)

One set of the fabrics (A1, B1 and C1) act as control and washed with only water and rinsed with water.

Another stet of the fabrics (A2, B2 and C2) was washed with combination of water and anti-bleeding solution in the ratio of 30:10 cm^3 respectively. These samples were rinsed thoroughly with water

The last sets of the fabrics (A3, B3 and C3) were washed with combination of water and anti-bleeding solution in the same ratio as stated above. This was rinsed with water and anti-bleeding in the ratio 35:5 cm^3 respectively.

These washed fabrics were dried overnight at room temperature and kept for this analysis. The load-elongation at break of the above textile material was done at a constant rate of elongation at 500N per tension at 25°C and Relative humidity of 65% on Instron universal testing machine Tensile Tester, (RS232) [13-14].

2.2.2. Analysis of the Effluent

The effluents generated when washed with varying ratio of anti-bleeding to soap and detergent solution respectively and effluents for washing with soap and detergent solution were analyzed for BOD5, conductivity, temperature, turbidity, DO, pH, TDS, TSS and TS. These were carried out as a follow up procedure to Adetuyi *et al*. [9]

a. Total suspended solid (TSS)

Suspended solids or non-filterable solid of the effluent sample was determined gravimetrically. Whatman filter paper (number 4) used was oven dried at a temperature of 105°C for 1h. After which it was placed in a desiccator to cool. It was removed and weighed using a calibrated weighing balance and recorded as W1. 40 cm^3 of the sample was filtered with the filter paper; the filtrate was then place in an oven for 1 hr at a temperature of 105°C then cooled until a constant weight was obtained. The filtrate with the paper were weighed after drying and the weight recorded was W2 [15-16]. The TSS value was calculated using the formular:

$$Total\ Suspended\ Solid\ (TSS)\ mg/L = \frac{W_2 - W_1}{Volume of the Sample\ (ml)} x\ 1000$$

Where W2= weight of the solids+ filter paper

W1= weight of the filter paper.

b. Total dissolved solids (TDS)

The sample was filtered using Whatman filter paper (number 4), that was oven dried at 105°C. Exactly 100 cm^3 of the filtrate was then transferred into a previously weighed evaporating dish (W1). This was evaporated to dryness on electric hot plate before drying to a constant weight in an oven at 105°C. The content was kept in a desiccator and allowed to cool before the weight (W_2) was taken [15, 17]. The TDS value was calculated using formula:

$$Total\ Dissloved\ Solid\ \ (TDS) mg/L = \frac{W_2 - W_1}{Volume\ of\ the\ Sample\ (ml)} x\ 1000$$

Where W_2= weight of the dish and residue

W_1= weight of the dish.

Total solid (TS)

The value for total solid was calculated as it is the summation of the total dissolved solid and total suspended solid.

Calculation

Total solid (mg/L) = TSS + TDS

Where

TSS = Total suspended solid

TDS= Total dissolved solid

3. Results and Discussion

3.1. Tensile Strength Properties of the Laundered Textile Apparels

The tensile strength parameters of the textile samples are shown in Tables 1-2 for samples washed with soap and detergent. Compared with the control textile samples (A1 B1 C1) having a tensile strength of 349.50 for Sample A, 274.52 for sample B and 72.37 for Sample C, the textile apparel treated with anti-bleeding solution during washing and rinsed with a combination ratio of the water and anti-bleeding formulation (5:35 cm^3) have higher tensile strength value of 366.57 for sample A, 272.92 for sample B and 1133.55 for sample C.

Generally, textile apparels in use and washed are subject to a variety of forces, which are repeated many times during wash until finally the apparel wears out. Hence, the life of textile apparel is a function of its resistance to abrasion [18].

However, when washed with detergent there is reduction in the tensile strength of the textile apparel. This action agrees with the investigation carried out by Jianhua and Ning [19] which shows that hydrolysis of cotton yarn with slightly acidic or alkaline of solution causes reduction to set in the in tensile strength of the fabrics especially when washed with detergents. Research also reveals that the interaction of chemical constituents present in the soap and detergent used with the fabrics fibre matrixs reduces the tensile properties of the fabrics which in turn reduce its work of rupture (Table 1 and 2) [20-21]. Consequently, these strength properties are decisive parameters for filament fabric. Low strength properties shorten the useful life time as well disables the functionality of these products. The strength properties of woven fabrics are a complex phenomenon and can be affected by different constructional parameters and various axillaries in solution introduced during laundry processes [22-24]. However, the addition of the anti-bleeding solution improves the tensile strength properties of the textile apparel washed in soap solution. This can be as a result of forestalling of bleeding on bleeding textile apparels and the interaction of the alkaline constituents with its acidic counterpart. Thus, provides a milder laundry conditions for the apparel [9].

Table 1. Tensile Strength for Textile Samples Laundered with Soap.

Test Samples	Load At Max Tensile Strength	Breaking Load (N)	Elongation (mm)	% Extension	Work of Rupture (J)
A1	349.50257	181.04876	9.25006	9.25	1026.752
B1	274.52202	84.50382	13.08344	26.17	1429.625
C1	72.36662	36.02295	7.50006	15.00	167.7321
A2	339.37849	142.91721	9.50012	19.00	508.6207
B2	284.30307	114.33756	10.66675	21.34	158.1147
C2	245.32333	172.36889	9.66669	19.34	250.3335
A3	366.59597	170.59360	9.33337	18.66	941.2088
B3	272.92906	135.88611	12.83337	25.66	481.6904
C3	133.55459	24.98383	7.75000	15.5	283.0055

Table 2. Tensile Strength for Textile Samples Laundered with Detergent.

Test Samples	Load At Max Tensile Strength	Breaking Load (N)	Elongation (mm)	% Extension	Work of Rupture (J)
A1	421.93169	177.28126	11.58331	23.16	1026.752
B1	312.76525	219.94233	13.00000	26.60	1429.625
C1	104.15744	35.53623	9.44006	18.88	167.7321
A2	387.96358	83.02826	12.25175	24.50	508.6207
B2	124.14701	41.24686	7.66675	15.34	158.1147
C2	92.68224	56.14943	8.91669	17.84	250.3335
A3	380.90819	168.57346	11.16675	22.34	941.2088
B3	311.26151	77.07010	12.50006	25.0	481.6904
C3	121.75116	56.38475	10.03837	20.08	283.0055

3.2. Result of Effluent Analysis

Tables 3 and 4 shows the result of the physicochemical properties of corresponding effluents. The effluents result from washing with varying ratio of anti-bleeding to soap and detergent solution respectively and effluents for washing with soap and detergent solution only. This was after 10:30 $cm^3$of anti-bleeding to water ratio per 2.8 g + 0.5 of textile samples was introduced to the solution. The values of the total suspended solids (TSS) and total dissolved solid (TDS) was accessed and compared with the values prescribed by the Standard organization of Nigeria (SON). The untreated textile samples (A1, B1 and C1) have TSS of 1.34, 2.46, 2.17 mg/L while its TDS are 136, 99.75 and 20.50 mg/L for soaps which is above the SON dischargeable limits.

Robinson *et al*. [25] and Saadia *et al*. [26] reports that huge amount of dyes and colloids consisting of various chemicals from textile effluent discharged are continuously being disposed into streams due to their poor absorption of the dyes back into the fibre during dyeing, printing and during laundering operation of most deeply coloured textiles.

Furthermore the, environmental implication of the dyes is such that up to 50% of the initial dye mass (up to or exceeding 800 mgL^{-1}) used in the dyeing process remains in the spent dye bath in its hydrolyzed form which no longer has an affinity for the fabric. This is also similar to laundering operation of bleeding textile apparel. The presence of very small amounts of dyes in water during the industrial processes and domestic laundry operations (less than 1 ppm for some dyes) is highly visible and affects the aesthetic merit, water transparency and gas solubility in lakes, rivers and other water-bodies [26]. This renders them more stable and less amenable to biodegradation. And consequently increasing certain physicochemical parameters of the water bodies above the tolerable limit for aquatic life [27].

However when the effluent of the treated textile samples were analyzed, the values for both TSS and TDS as shown in Tables 3 and 4, is below the SON dischargeable limit for washing with soap or detergent. This case can be as result of the low turbidity of the effluent based on the effective anti-bleeding control action of the formulation. The pH ranges within 7.5-8.5 for the effluent of the treated textile samples washed with detergent, while the untreated has a pH range slightly alkaline and higher than the acceptance value (6.50-8.50) as prescribed by SON. However, for the treated and untreated samples washed with soaps, the pH range is in compliance with SON. The values of this parameters below the tolerable limit can be said to be as a result of the incorporation of the anti-bleeding formulation which reduces bleeding process of the textile samples and thus. Pollution prevention opportunities were also accomplished on the basis of process modifications or via the use of greener technologies, chemicals in different branches of the textile sector and incorporation of this formulation for laundry purposes [28-32].

Table 3. Textile samples washed with varying ratio of anti-bleeding and soap solution.

Samp	pH	SON Standard	CND (mm/cm)	SON standard	Turbidity	SON standard
A1	8.30	6.50-8.50	43.5	<2000	90.0	50.00
B1	9.86	6.50-8.50	56.0	<2000	99.5	50.00
C1	7.31	6.50-8.50	34.5	<2000	814	50.00
A2	8.33	6.50-8.50	28.33	<2000	39.67	50.00
B2	8.27	6.50-8.50	51.0	<2000	41.5	50.00
C2	7.691	6.50-8.50	96.67	<2000	22.5	50.00

Table 3. Continued.

Samp	Temp (°C)	TDS (mg/L)	SON standard	TSS (mg/L)	SON standard	TS (mg/L)
A1	25.4	136.00	50.00	1.3375	100.0	137.34
B1	25.3	99.75	50.00	2.4575	100.0	102.21
C1	25.4	20.50	50.00	2.1675	100.0	22.67
A2	25.3	52.25	50.00	0.585	100.0	52.84
B2	25.4	21.75	50.00	2.3400	100.0	24.09
C2	25.4	6.56	50.00	0.4975	100.0	7.06

Key: Samp= Textile Samples
CND= Conductivity
Temp= Temperature
TDS= Total dissolved Solid
TSS= Total Suspended Solid
TS = Total Solid
Control Textile samples: $A_1B_1C_1$
Treated Textile Samples: $A_2B_2C_2$

Table 4. Textile samples washed with varying ratio of anti-bleeding and detergent solution.

Samp	pH	SON Standard	CND (mm/cm)	SON standard	Turbidity	SON standard
A1	9.66	6.50-8.50	650.33	<2000	130.5	50.00
B1	8.62	6.50-8.50	644.67	<2000	188.5	50.00
C1	9.6	6.50-8.50	878.33	<2000	110.0	50.00
A2	8.33	6.50-8.50	373.67	<2000	76.0	50.00
B2	7.96	6.50-8.50	51.0	<2000	93.5	50.00
C2	8.00	6.50-8.50	96.67	<2000	89.5	50.00

Table 4. Continued.

Samp	Temp (°C)	TDS (mg/L)	SON standard	TSS (mg/L)	SON standard	TS (mg/L)
A1	25.4	12.00	50.00	39.75	100.0	51.75
B1	25.0	21.75	50.00	20.25	100.0	42.00
C1	25.4	39.25	50.00	9.75	100.0	49.00
A2	25.0	12.25	50.00	15.00	100.0	27.50
B2	25.0	26.75	50.00	9.00	100.0	35.75
C2	25.10	18.75	50.00	6.00	100.0	24.75

Key: Samp= Textile Samples
CND= Conductivity
Temp= Temperature
TDS= Total dissolved Solid
TSS= Total Suspended Solid
TS = Total Solid
Control Textile samples: $A_1B_1C_1$
Treated Textile Samples: $A_2B_2C_2$.

4. Conclusion

The multicoloured textile apparel laundered with anti-bleeding solution alongside with bar soap and detergent respectively, exhibit a good tensile strength after the wash and their corresponding effluent is within the tolerable limit Set by standard organization of Nigeria (SON).

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