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RESEARCH ARTICLE

Reuse of dye effluents into the fresh batch dyeing with the variation of chemical and dye percentages

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Abstract

Objectives: To study the reuse of dye effluents in order to minimize the dyeing cost. **Methodology**: In this study, the exhausted dye effluents were reused into 7 new dyeing baths along with 7 different percentages of dyes and chemicals to evaluate the color fastness properties as well as shade difference. Firstly, the exhausted dye effluents were collected from the dye bath of the standard sample after dyeing was completed. Then respectively added extra 80%, 70%, 60%, 50%, 40%, 20% and 0% of the dyes and chemicals in the 7 different new baths where dye effluents of standard sample dyeing existed. After dyeing, all the 7 samples were collected and tested with ISO methods for the assessment of color fastness to Wash and color fastness to Rubbing. Moreover, all the samples were analyzed against the standard one with the help of a Spectrophotometer. **Findings**: From the overall testing reports, it had found that color fastness to wash and rubbing were satisfactory for all samples. But the CMC decision revealed that the sample which was treated along with the presence of an extra 80% dyes and chemicals in dye effluents showed minimum shade difference from the standard sample. So, it can be said that about 20% of dyes and chemicals can be saved by reusing dye effluents which can largely influence not only the environmental issues but also the cost-effectiveness of dyeing industries.

Keywords: Color Fastness; Cost-effectiveness; Dye Effluents; Environment; Reuse; Shade Difference

1 Introduction

In the traditional way of dyeing in textile industries, there were few approaches to environmental safety measures. Effluents from industries were discharged in the water sources. These obnoxious steps lead us to a disastrous consequence in today's earth. In this crisis, we need to focus on 3R principles i.e. Reduce, Reuse and Recycle through which sustainable movements in the manufacturing sectors will be accomplished.

Reuse of dye effluents in further dyeing process can make a tremendous turn in the dyeing industries, having a concern in mind about environmental risks along with minimization of dyeing cost. In this era of climatic climax, sustainable approaches for the development of textile processing are necessary for our future environment. Raising concern about sustainability through the recycling methods of effluents in textile manufacturing processes has become a buzzword in this climacteric situation of the world. Besides, the level of underground water is decreasing day by day due to use of this source at a large scale in the textile industry. Amidst all of the textile manufacturing industries, dyeing mills are the most water-consuming sector[1]. As this is the area of huge water consumption, it already made itself a reason for the water pollution by emitting all the pollutants, chemicals, dyeing liquor, etc. in the environment[2]. Along with high pH, temperature, BOD, COD, TDS, and TSS, exhausted textile effluents are usually colored. In the fabric coloration process because of using various dyes and pigments, dye molecules are permeated to the discharged effluents[3]. For marine lives, this discharged wastewater will be liable for creating an austere mess. Due to having a complex molecular structure in the dye molecules & a synthetic source, they become more stable and harder to be biodegraded in the environment[4,5].

At first sight, the fascination of any fabric is color. Even though having an excellent composition, it is figured to be a failure as a commercial product if that is colored in an unsuitable way[6]. From ancient times people extracted dyes from natural substances and dyed with that[7]. But due to poor wash & colorfastness properties, those processes did not become popular[8]. In 1856, W. H. Perkins discovered synthetic dyes that have scattered a variety of dyes which are colorfast in nature and appear in not only a wide range of color but also brighter shades[9]. And by this sequence, many types of synthetic dyes had been invented and developed while some dyes are difficult to biodegrade; particularly the hydrolyzed reactive and certain acidic dyes are not readily absorbed by active sludge. Within all textile fibers, cotton fibers are nearly 48% that gets used for clothing all over the world and with reactive dyes, 20% of those are dyed[10].

More than 85% of redundant matter can be removed by a certain combination of various effluent treatment methods[11]. As textile industries use a large amount of water, eventually they generate high wastewater and generate risky effluents for human health. Because of the diversification of products, the textile industry has a range of subsidiary industries with operations and processes[12]. For dyeing 1kg of cotton fabric, around 110 liters of water is required and consequently a textile mill in which the capacity could be only 8 tons/day and a consumption of about 1.6 million liters of water per day[13]. It is also roughly calculated that to process one meter of cloth, 12-65 liters of water are needed. To develop a cotton T-shirt, it requires 257 gallons of water[14]. Because of heavily charged with unconsumed dyes, this exhausts the effluent from textile industries, it becomes alarming for human life as well as very dangerous for aquatic life[15]. It is perceived that from different textile mills massive quantity of wastewater is discharged on a daily basis[16].

In the recent days, for industrial air and water pollution, public concern is approaching notable restrictions on all industrial activities which are polluting our environment[17]. As soon as possible, it is needed to diminish the growth of consumption from fossil fuels, water, and energy and reduce the use of these natural resources. Wastewater and output to the environment from production should be lessened in volume which also decreases the negative impact on the environment[18].

In this project, reuse of dye effluents has been done and an effective result has been obtained. By the result of this study, a statement can be developed that without using ETP or WTP, we can partially recycle the wastewater from the dyeing bath and it can save around 20% of the dyeing cost in the dyeing industry.

2 Materials and Methods

2.1 Materials

2.1.1 Fabric

Single jersey 100% cotton knitted fabric, the fabric weight per unit area was 150 g/m^2 and collected from Ambia Knitting and Dyeing Ltd., Chittagong, Bangladesh.

2.1.2 Dye-stuffs

i. Reactive Dyes

(a) Sumifix Yellow EXF

(b) Sumifix HF Red 2B

(c) Sumifix Blue EXF

2.1.3 Chemicals

i. Leveling Agent

ii. Glauber's Salt

iii. Soda Ash

iv. Acetic Acid

v. Soaping Agent

2.1.4 Types of machinery

i. Laboratory Sample Dyeing Machine (Brand Name: Mathis; Model No: H-T2-000; Country of origin: China)

ii. Washing Fastness Machine (Brand Name: James Heal; Model No: 1615 20 Gyro-wash; Country of origin: UK)

iii. Crock meter/Rubbing fastness tester (Brand Name: James Heal; Model No: 680; Country of origin: UK)

iv. Spectrophotometer (Brand Name: x-rite; Model No: Color Eye 7000A; Country of origin: USA)

v. Color Matching Cabinet (Brand Name: Verivide; Model No: CAC-60; Country of origin: UK)

2.2 Methods

2.2.1 Sample preparation

The scoured and bleached fabric was collected from the mill. From that fabric 14 pieces of sample had been cut off for our experiment where the weight of each sample was 10gm. 1% stock solution of dyes and chemicals had been prepared. Dyes, chemicals, and fabric samples were weighted by using the digital electrical weight balance. Then the actual part of the experiment was started. By considering 2 Slots, 14 samples had been taken for this experiment.

Table 1. Identification of samples (slot wise and batch wise)

Slot–1	**Batch - 1**	**Batch - 2**	**Batch - 3**	**Batch - 4**	**Batch - 5**	**Batch - 6**	**Batch – 7**
				Standard Recipe			
Slot–2	Effluents + 0% Dyes and Chemicals	Effluents + 20% Dyes and Chemicals	Effluents + 40% Dyes and Chemicals	Effluents + 50% Dyes and Chemicals	Effluents + 60% Dyes and Chemicals	Effluents + 70% Dyes and Chemicals	Effluents + 80% Dyes and Chemicals
	Batch - A	Batch - B	Batch - C	Batch - D	Batch - E	Batch - F	Batch - G

2.2.2 Dyeing and after treatment process of standard batch (Batch-1 to Batch-7)

Firstly 7 samples (Batch-1 to Batch-7) were dyed with an ideal reactive dyeing recipe mentioned in Table 2. After dyeing, dye effluents were collected from every batch and all samples were firstly washed with water then treated with acetic acid followed by soaping as mentioned in Table 2. Finally, the samples were squeezed and then dried in the oven dryer machine at 120°C for 5 minutes.

Table 2. Dyeing recipe of Batch-1 to Batch-7

Sample Weight - 10 gm			**Liquor Ratio – 1:40**	
		Dyeing Recipe		
Water	**Dyes and Chemicals**	**% or g/L**	**Time**	**Temperature**
Fresh Water 400 ml	Leveling Agent	1.5 g/L	60 min	60°C
	Sumifix Yellow EXF	0.5%		
	Sumifix HF Red	1.0%		
	Sumifix Blue EXF	0.5%		
	Glauber's Salt	40 g/L		
	Soda Ash	10 g/L		
		After Treatment Recipe		
Fresh Water 400 ml	Acetic Acid	0.5 g/L	5 min	55°C
Fresh Water 400 ml	Soaping Agent	1.5 g/L	10 min	80°C

2.2.3 Dyeing and after treatment process of Batch-A to Batch-G

Batch-A, Batch-B, Batch-C, Batch-D, Batch-E, Batch-F, and Batch-G had been prepared by using those dye effluents of Slot-1 and added extra 0% (Batch-A), 20% (Batch-B), 40% (Batch-C), 50% (Batch-D), 60% (Batch-E), 70% (Batch-F) and 80% (Batch-G) dyes and chemicals into all the batches of Slot-2. Here dyeing and after treatment parameters (Time, Temperature and ratio M: L) were carefully maintained as per standard sample treatment.

Table 3. Dyeing recipe of Batch-A

Sample Weight - 10 gm			**Liquor Ratio - 1:40**	
Water	**Dyes and Chemicals**	**% or g/L**	**Time**	**Temperature**
400 ml Dye Effluents	No Dyes and Chemicals	N/A	60 min	60°C

After completing the whole process, all the samples were tested for Color Fastness to Wash with ISO 105 C06 A2S test method and Color Fastness to Rubbing with ISO 105 X12 test method. And all the samples were also analyzed with Spectrophotometer for getting the Color Difference with the standard one.

Table 4. Dyeing recipe of Batch-B

Sample Weight - 10 gm			Liquor Ratio - 1:40		
Water	**Dyes and Chemicals**	**Newly Added %**	**% or g/L**	**Time**	**Temperature**
400 ml Dye Effluents	Leveling Agent	20% dyes and chemicals	0.3 g/L	60 min	60°C
	Sumifix Yellow EXF		0.1%		
	Sumifix HF Red		0.2%		
	Sumifix Blue EXF		0.1%		
	Glauber's Salt		8 g/L		
	Soda Ash		2 g/L		

Table 5. Dyeing recipe of Batch-C

Sample Weight - 10 gm			Liquor Ratio - 1:40		
Water	**Dyes and Chemicals**	**Newly Added %**	**% or g/L**	**Time**	**Temperature**
400 ml Dye Effluents	Leveling Agent	40% dyes and chemicals	0.6 g/L	60 min	60°C
	Sumifix Yellow EXF		0.2%		
	Sumifix HF Red		0.4%		
	Sumifix Blue EXF		0.2%		
	Glauber's Salt		16 g/L		
	Soda Ash		4 g/L		

Table 6. Dyeing recipe of Batch-D

Sample Weight - 10 gm			Liquor Ratio - 1:40		
Water	**Dyes and Chemicals**	**Newly Added %**	**% or g/L**	**Time**	**Temperature**
400 ml Dye Effluents	Leveling Agent	50% dyes and chemicals	0.75 g/L	60 min	60°C
	Sumifix Yellow EXF		0.25%		
	Sumifix HF Red		0.5%		
	Sumifix Blue EXF		0.25%		
	Glauber's Salt		20 g/L		
	Soda Ash		5 g/L		

Table 7. Dyeing recipe of Batch-E

Sample Weight - 10 gm			Liquor Ratio - 1:40		
Water	**Dyes and Chemicals**	**Newly Added %**	**% or g/L**	**Time**	**Temperature**
400 ml Dye Effluents	Leveling Agent	60% dyes and chemicals	0.9 g/L	60 min	60°C
	Sumifix Yellow EXF		0.3%		
	Sumifix HF Red		0.6%		
	Sumifix Blue EXF		0.3%		
	Glauber's Salt		24 g/L		
	Soda Ash		6 g/L		

Table 8. Dyeing recipe of Batch-F

Sample Weight - 10 gm			Liquor Ratio - 1:40		
Water	**Dyes and Chemicals**	**Newly Added %**	**% or g/L**	**Time**	**Temperature**
400 ml Dye Effluents	Leveling Agent	70% dyes and chemicals	1.05 g/L	60 min	60°C
	Sumifix Yellow EXF		0.35%		
	Sumifix HF Red		0.7%		
	Sumifix Blue EXF		0.35%		
	Glauber's Salt		28 g/L		
	Soda Ash		7 g/L		

Table 9. Dyeing recipe of Batch-G

Sample Weight - 10 gm			Liquor Ratio - 1:40		
Water	**Dyes and Chemicals**	**Newly Added %**	**% or g/L**	**Time**	**Temperature**
400 ml Dye Effluents	Leveling Agent	80% dyes and chemicals	1.2 g/L	60 min	60°C
	Sumifix Yellow EXF		0.4%		
	Sumifix HF Red		0.8%		
	Sumifix Blue EXF		0.4%		
	Glauber's Salt		32 g/L		
	Soda Ash		8 g/L		

Table 10. After-treatment recipe of Batch-A to Batch-G

Sample Weight - 10 gm		Liquor Ratio - 1:40		
Water	**Dyes and Chemicals**	**% or g/L**	**Time**	**Temperature**
Fresh Water 400ml	Acetic Acid	0.5 g/L	5 min	55°C
Fresh Water 400ml	Soaping Agent	1.5 g/L	10 min	80°C

3 Results and Discussion

3.1 Assessment of color fastness to wash

Table 11. Wash fastness properties of dyed samples

Samples	Changein Color	Color Staining					
		Acetate	Cotton	Nylon	Polyester	Acrylic	Wool
Batch 1 to 7 (Standard)	4/5	4/5	4	4/5	4/5	4/5	4/5
Batch A	4/5	4/5	4/5	4/5	4/5	4/5	4/5
Batch B	4/5	4/5	4/5	4/5	4/5	4/5	4/5
Batch C	4/5	4/5	4	4/5	4/5	4/5	4/5
Batch D	4/5	4/5	4	4/5	4/5	4/5	4/5
Batch E	4/5	4/5	4	4/5	4/5	4/5	4/5
Batch F	4/5	4/5	4	4/5	4/5	4/5	4/5
Batch G	4/5	4/5	4	4/5	4/5	4/5	4/5

From Table 11, it is shown that the change in color due to wash is the same for all samples. But for color staining, there was a slightly better result for Batch A and Batch B in case of cotton fibre. These have happened because the low concentration dyes and chemicals were used for those batches, one consumes 0% extra dyes and another is 20%. Lower the dye uptake %, lower the possibility of color staining.

3.2 Assessment of color fastness to rubbing

Table 12 shows that the dry rubbing fastness of all samples is the same. But in case of wet rubbing, there was a slightly better result for Batch A and Batch B rather than other batches because they are a lighter shade among them and have a tendency to give better rubbing fastness.

3.3 Measurement of color difference

CIE color coordinates include color qualities in terms of L* (Lightness and Darkness), a* (Redness and Greenness), b* (Yellowness and Blueness), C* (Chroma) and H* (Hue) of the samples of Slot-1 are shown

Table 12. Rubbing fastness properties of dyed samples

Samples	Dry Rubbing	Wet Rubbing
Batch 1 to 7 (Standard)	4/5	4
Batch A	4/5	4/5
Batch B	4/5	4/5
Batch C	4/5	4
Batch D	4/5	4
Batch E	4/5	4
Batch F	4/5	4
Batch G	4/5	4

in the table.Here, considering Slot-1 samples as Standard and Slot-2 samples were analyzed.

Table 13. The difference of color coordinates between standard and samples

Standard	Samples	Illuminant/ Observer	DL*	Da*	Db*	DC*	DH*	DE	Remarks
Batch 1 to 7	Batch A		29.94	-0.69	1.70	-1.05	1.50	17.33	Fail
	Batch B		16.85	2.44	0.42	2.27	0.98	9.85	Fail
	Batch C		8.03	1.36	0.42	1.22	0.74	4.73	Fail
	Batch D	D65/10 Deg	4.49	1.63	0.85	1.39	1.20	2.89	Fail
	Batch E		5.01	0.84	0.82	0.63	0.99	3.04	Fail
	Batch F		1.82	0.41	0.89	0.19	0.96	1.32	Fail
	Batch G		0.66	0.25	0.87	0.03	0.91	0.83	Pass

From Table 13, it is shown that Batch A exhibits higher color difference and this color difference gradually reduced for Batch B to Batch G. This has happened due to the addition of extra dyes and chemicals. But, only Batch G showed the color difference in the tolerable range as DE is less than 1.

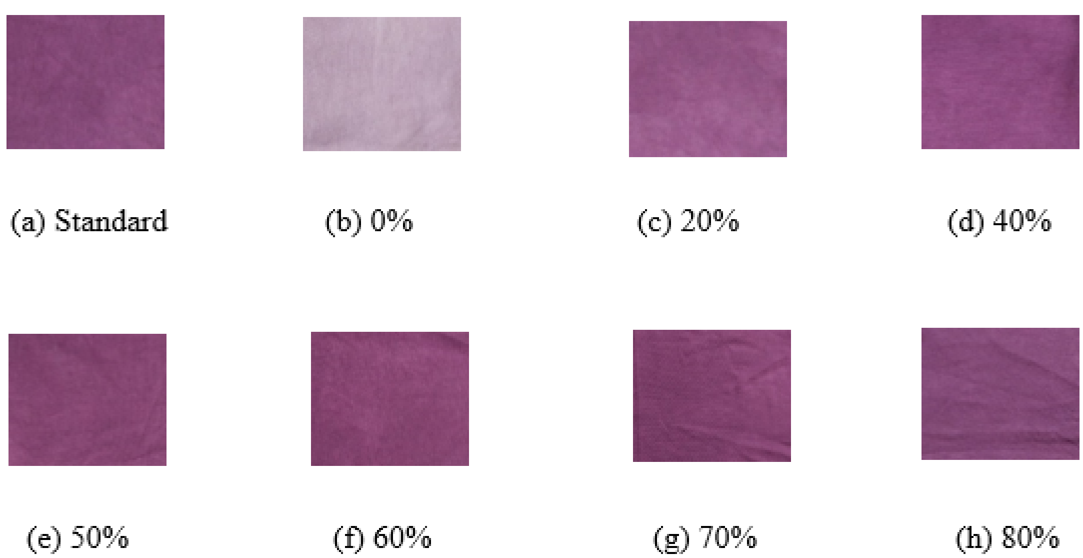

Fig 1. Physical shade difference among the Batches

From the overall experimented assessments and results, it is visible that Batch G shows an impressive result. It shows an excellent grey scale rating of color fastness to wash and rubbing. Moreover, the color difference value of Batch G (DE=0.83) is in the acceptable range.

So, under the above circumstances, a final statement can be declared that not only effluents can be reused but also with using the effluents, same shade of certain color can be achieved by saving a maximum 20% of dyes and chemicals which also saves dyeing costs and can be less hazardous for our environment as well as the water source.

4 Conclusion

In this study, dye effluents had been successfully reused and 20% of dyes and chemicals were saved with a better-quality product. This experiment can be a great turn in the field of textile wet processing as well as the individuals who have a deep concern about water and chemical consumption. Looking forward to a green world, we have to be more conscious about our surroundings and not to avoid any of the elements that can be reused.

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Conflicts of Interest

The authors have no conflicts of interest.

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