

Direct Reusing of Textile Wastewater in Scouring-Bleaching of Cotton Goods Devoid of Any Treatment

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Abstract:- Reusing of textile wastewater is generally based on some sorts of wastewater treatment process before reusing. Current paper discusses the direct reusing of textile wastewater without any treatment which not only can reduce the freshwater consumption rate but also reduce the effluent load. Six different types of rinsing wastewaters were studied. Wastewaters were segregated by collecting them separately from the drain line of dyeing machine. Then collected wastewaters were used for the scouring bleaching of knitted cotton fabric. Few specific types of rinsing water have showed bright prospect of reusing. Among them, one type of 'before dyeing rinsing' water has found to be quite acceptable and safe to reuse for the scouring-bleaching of cotton goods. Bleached samples were then dyed to investigate the dyeing performance. Weight loss of scoured-bleached sample has found 6.65% for wastewater and 6.53 % for fresh water. Reflectance of whiteness of bleached wastewater and fresh water samples have found 76.68% and 77.92 % respectively whereas the shade variation between them was only 0.62 (ΔE value) which is quite acceptable. Absorbency of bleached samples have also found excellent. After dyeing, the variation of shade between fresh water and wastewater treated samples have found 0.65 (ΔE value) which is also well below the maximum acceptable limit. Beside this, Fastness rating of wastewater treated samples were 4/5, 4 and 4/5 for rubbing, washing and perspiration fastness respectably.

Key words:- Effluent, Wastewater reuse, Groundwater, Environment,

I. INTRODUCTION

Textile and readymade garments (RMG) industries are the economic backbone of Bangladesh. This sector is contributing to the income of around 15 million peoples and offering more than 77% of total national exports [1, 2]. Through backward and forward linkage economic activities, RMG sector of Bangladesh gradually injected dynamism in the domestic economy [1, 3-5]. Moreover, the textile and RMG sector is the main source of female employment in Bangladesh [6-8]. As an emerging industry, the export-oriented RMG sector of Bangladesh shows exceptionally high growth rate of 15% per annum which is higher anywhere in the world. Bangladesh RMG era started in 1973 when only one industry exported US\$69 thousand. In 2002 export from RMG reached to US\$ 4.5 billion from more than 3400 industries [3] countrywide. In 2011 total export earning was US\$12 billion from 5000 factories and according to a reputed global management consulting firm, this amount will rise upto \$36b to \$42b within next 10 years [4].

However the industrial growth of the country is threatening the environment. Textile industries generates risky effluent for human health as they use huge amount of water and eventually generate high wastewater[9]. Nearly 110 liters of water is needed to dye 1kg cotton fabric and thus the water consumption of an average sized textile mill having capacity only 8 tons/day is about 1.6 millions liters per day [10, 11]. Among the textile fibers , about 48% are cotton fibers that we consumed as clothing materials all over the globe and 20% of those are dyed with reactive dyes [12, 13]. Reactive dyes are water soluble compound exhibit functional group capable of forming covalent bond. After dyeing, discharged dye liquor contained considerable amount of dissolved color [14] and unfixed hydrolyzed dyes [15]. This effluent from textile industries are heavily charged with unconsumed dyes, various chemicals, surfactants and sometimes with traces of metals [16] which causes environmental problems when discharged into the surface and ground water bodies. It has been found that nearly 15% of the total world production of dyes is drained from dyeing machine as unconsumed in dyeing process and discharged as textile effluent [17]. Wastewater from textile industry is not only dreadful for human life but also very dangerous for aquatic life.

Suspended solids can clog fish gills, either killing them or reducing their growth rate. Again it also reduces the light penetration and thus lower the production of algae[18].

Saving our environment is a question out of debate. Considering the danger of industrial waste stream, government and community are becoming more concern about environmental issues. Textile industries are facing increasing number of challenges from environmental issues and environmental legislation which includes increased cost of water, increased cost of effluent treatment and disposal, implementation of more stringent regulations , ecolabels and new legislation especially in terms of color, toxicity and salinity; and the introduction of ISO 14001 [19]. Dyeing factories, polluting the water bodies will face the threat of shutting down [20] and this has already started in Bangladesh [20, 21]. In order to meet these challenges, many researchers are suggesting wastewater reuse [22-27] and the industrialists have also started adopting clean technologies as to consume less natural resource and generate less waste [28].

Current research paper discusses the possibilities of without treatment reusing of textile wastewater in the same factory. Industries do not need water as pure as for drinking purpose. Hence, they can reuse their wastewater. This research project has illustrated the possibilities of reusing the textile wastewater without any wastewater treatment process. It is an appropriate, cost effective water recycling method for reducing the pollution level and fresh water consumption rate. Wastewater stream of the textile industries are generally not be segregated and hence can not be reuse without treatment. This project has been found that there are few wastewater streams which can be reused without any treatment by segregating them from other types of wastewater. Current research work was carried out on knitted cotton fabric dyeing industries. Wastewater of knit dyeing industry is variable in character. Such as, wastewater from bleaching , enzyme treatment, dyeing and washing bath contain high level of contamination (TSS,TDS) and can not be used without treatment. However, the contamination level of the wastewater from rinsing operation is very low and almost colorless in nature. Hence, these type of water has good prospect to be reused without any treatment. This rinsing wastewater from different stages of dyeing process had collected in periodic basis and analyzed. Then they were used for the scouring-bleaching and dyeing purpose. Scouring-bleaching and dyeing performance of these samples were then compared against the samples prepared by using fresh water.

II. LITERATURE REVIEW

Previous research works have showed bright opportunity of reusing textile wastewater. However, The existing reusing methods of industrial wastewater are not as cheap as comparatively easily available fresh water. It has been said that membrane treated wastewater can be reused in every stage of commercial dyeing [25, 29]. Few other methods to treat textile wastewater are adsorption process [30-35], coagulation method [36-38], filtration [39-41], biological [42] and enzymatic technique [43], Fenton process [44] , sonochemical process [45-48], electrochemical process [49-51], ion exchange [52], supercritical water oxidation [53-55] etc. A research work by United States Environmental Protection Agency showed that waste water from bleaching can be effectively reused in the scouring bath[56] without any treatment. Ayaz has presented diversified reuses of textile wastewater such as-water used in water-jet weaving machine can be reused in the same machine or in the dyeing machine for scouring and bleaching; wastewater from mercerizing can be used for scouring; dye bath rinse water can be used for dye bath make up; soaping wash water for further washing and the cooling water can be used directly in the process [57]. However most of the reusing and wastewater treatment techniques are not comfortably acceptable to the factory owners due to additional operational and maintenance cost. Hence process shown in this paper can be a comfortable choice to the industrialist. The present research work is a novel method showing the possibility of reusing textile wastewater directly for the scouring-bleaching of cotton goods without any water treatment process. It is free from additional treatment cost but can reduce huge amount of freshwater to be consumed for the same purpose.

III. EXPERIMENTAL

3.1 MATERIALS AND METHODS

3.1.1 MATERIALS:

Fabric: Single Jersey cotton knitted fabric.

Dyes & Chemicals: Wetting agent (Americos Wettex 800), Leveling agent (Americos Leveler LE), Sequestering Agent (Americos Sequester 2000), Peroxide Stabilizer (Americos Stabilizer NBL), laboratory grade Soda ash (Merck), Hydrogen peroxide (Merck), Caustic soda (Merck), Reactive Dyes (Remazol Red RR), Electrolyte (common salt), ISO certified detergent (Heal's ECE Formulation).

Equipments: SANDOLAB Infrared laboratory dyeing machine (model no: SUPERMAT V) made by Copower Technology Co. Ltd. Taiwan; CROCKMETER (mode no: 670) rubbing fastness tester from James H Heal & Co,

UK; GYROWASH (model no: 415/8) wash fastness tester from James H Heal & Co, Uk; PERSPIROMETER (model: HX-30) perspiration tester from James H Heal & Co, Uk; Varidide (model: CAC-60) Color matching cabinet from Verivide, Uk.

3.1.2 TEST METHODS:

Absorbency of scoured-bleached samples was analyzed in spot/drop test method. Fabric destruction due to scouring-bleaching was determined by calculating the weight loss. Whiteness of bleached fabric and shade variation of dyed samples were analyzed through measuring the reflectance by using DataColor software in a spectrophotometer. Color fastness to wash was tested in ISO 105 C06 test method, Colorfastness to crocking was tested according to ISO 105 X12, 1993 test method, Colorfastness to perspiration was tested in ISO 105 E04, 1994; BS EN ISO 105 E04,1996 test method.

3.2 METHODOLOGY

3.2.1 SAMPLE PREPARATION:

Wastewater were collected from two 100% export oriented commercial textile knit fabric dyeing industries , namely TEXEUROPE (BD) LTD and VIYELLATEX GAZIPUR Bangladesh. To segregate, wastewaters were collected directly from the draining outlet of dyeing machine after completion of each stage. 10 wastewater samples were taken for scouring-bleaching, dyeing and performance analysis tests from every collection stages along with a mixed water (all type of wastewater mixed in equal volume) and fresh water sample. Fabric samples taken were 5gm according to the lab dyeing machine specifications. Results shown in the graphs, tables and charts are the average results of 10 tests on each types of water.

3.2.2 WORK FLOW:

Wastewaters were segregated by collecting them separately from the drain line of dyeing machine. Water was collected from five pre-selected stages of a complete dyeing program as shown in table-1 and figure-

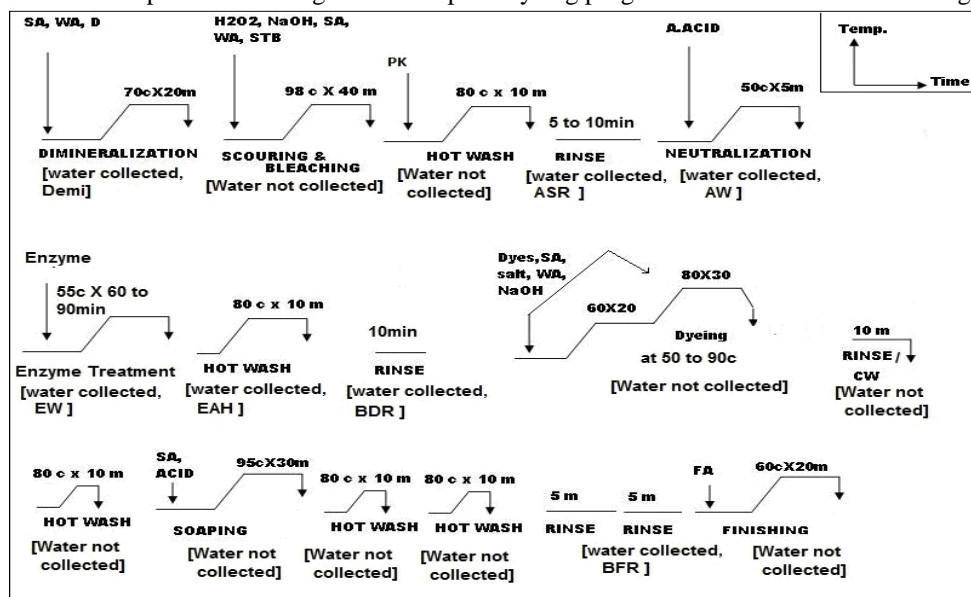


Figure-1: Flow diagram of a basic knit dyeing program showing different wastewater discharging stages. Given short names of the collected wastewaters is shown in bracket.

Table-1: Given Short names of different types of wastewater in different stages of dyeing program.

<u>Steps in Basic knit dyeing Process</u>	<u>Given Short Name of the steps</u>
Demineralization-----60 ⁰ C×15min	Demi
Scouring & Bleaching-----95 ⁰ C×45min	Water not collected
Hot wash with H ₂ O ₂ Killer -----80 ⁰ C×15min	Water not collected
Rinse for 5 to 10 min	ABR/ASR (After Scouring-bleaching Rinse)

Neutralization with Acid	AW (Acid Water)
Enzyme Treatment -----55 ⁰ C×60-90min	EW (Enzyme water)
Hot wash at 60 ⁰ for 15 min	EAH (Enzyme and Hot wash)
Rinse for 5 to 10 min	BDR (Before Dyeing Rinse)
Dyeing -----60 ⁰ C×60 min	Water not collected
Rinse 5 to 15 min	Water not collected
Hot wash at required temperature	Water not collected
Soaping	Water not collected
Hot wash	Water not collected
Rinse for 5 to 10 min	BFR (Before Finish Rinse)
Finishing	Water not collected

Wastewater parameters such as TSS, TDS, COD, and BOD, Fe, chloride, Color (Pt-Co), Turbidity, pH and hardness were studied and noted for reference. Then the collected wastewaters were used directly without any wastewater treatment process for the scouring and bleaching purpose of single jersey cotton knitted fabric. Scouring and bleaching performance in terms of absorbency, whiteness and weight loss were analyzed against the similar fabric samples scoured-bleached with fresh water. Three best performing wastewater treated scoured-bleached samples were then selected and dyed along with fresh water samples. Finally, Dyeing performance were analyzed in terms of shade matching and fastness of color.

In case of scouring-bleaching performance, absorbency was checked visually through sport test method; the deviation of whiteness was calculated by determining ΔE [12] values between fresh water and wastewater treated samples and finally the weight loss of all fabric samples were calculated in percentage to identify the damage of the fabric due to scouring and bleaching process. To avoid dyeing condition differences, each type of wastewater samples were dyed with a freshwater sample in the same dyeing pot at the same time. Dyeing performances were investigated in terms of shade matching and color fastness of the dyed fabric. Here shade matching was determined by the ΔE value of dyed fabric samples against freshwater samples from similar batch. Color fastness was tested by testing color fastness to wash, crocking and perspiration of wastewater and fresh water treated fabrics.

IV. RESULT AND DISCUSSION

4.1 RESULTS

The following graphs are the representation of the test results found for different types of wastewater (AW, ASR, EW, BDR, and BFR), mixed wastewater (MW) and fresh water (FW) treated fabric. Results for Scouring-bleaching performance are shown in weight loss and reflectance of whiteness graph and spot test figure. Dyeing performance is shown shade variation graph and fastness table of dyed samples.

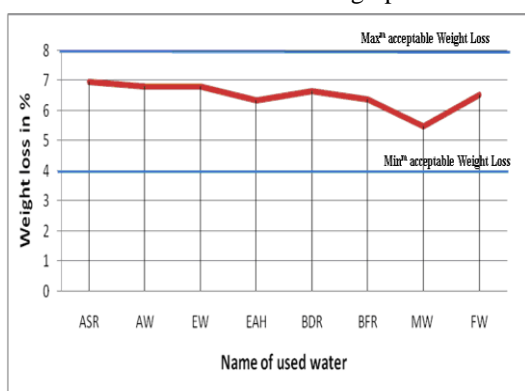


Figure 2: Comparing the average weight loss of scoured-bleached samples.

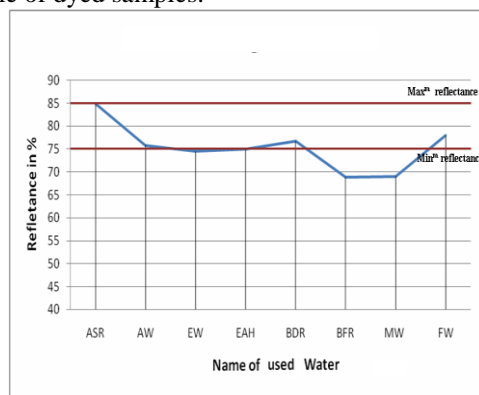


Figure-3: Average reflectance of white sample bleached with wastewater and freshwater..

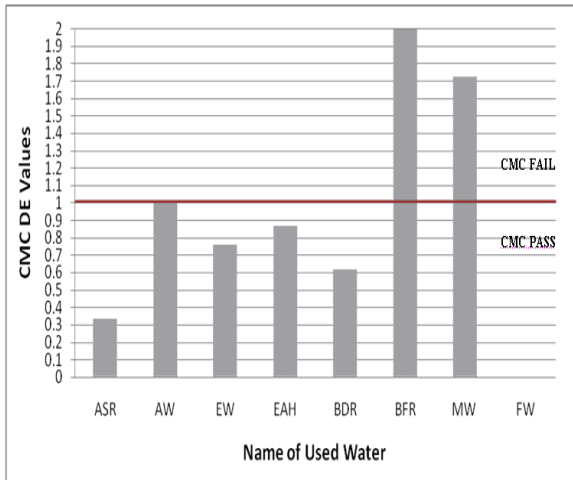


Figure-4: Average ΔE (of white bleached samples) of different wastewater treated samples against fresh water (FW) sample.

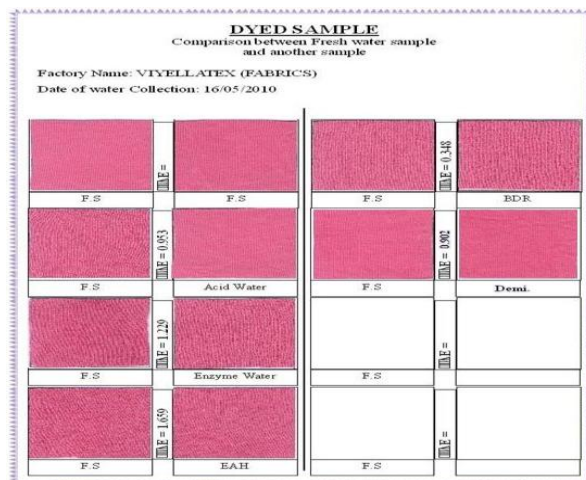


Figure-5: Shade card of different types of wastewater treated fabric samples against fresh water (FS) sample.



Figure-6: Physical appearance of top three wastewater treated (scoured-bleached) samples with grey and fresh water treated samples.

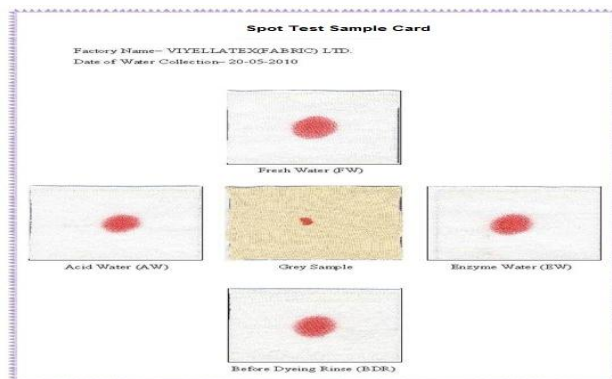


Figure-7: Spot test appearance of top three wastewater treated (scoured-bleached) samples with grey and fresh water treated sample.

Now the results of BDR wastewater collected from two different industries (Viyella tex Ltd and Texeuropa Bangladesh Ltd) at 10 different collection dates are given below-

Table-2: Scouring-bleaching and dyeing performance of BDR wastewater sample and fresh water sample

Collections (Factory name-Date), [VT=Viyellatex Ltd, TE=Texeuropa BD Ltd]	Scouring bleaching and shade matching [Before dyeing Rinse (BDR) and Fresh water (FW) sample]						Color Fastness rating of BDR wastewater treated dyed samples				
	Color Difference between fresh and Wastewater treated samples (ΔE)		Reflectance comparison of BDR and FW samples (%)		Weight Loss comparison of BDR and FW samples (%)		Rubbing fastness		Washing Fastness	Perspiration Fastness	
	Dyed	Bleached White	BDR	FW	BDR	FW	Dry	Wet		Acid	Alkali
VT-10/02/2010	1.668	0.85	75.43	77.62	6.05	5.35	4/5	4	4	4/5	4/5
VT-17/03/2010	0.36	0.75	65.92	61.13	5.99	5.5	4/5	4	4	4/5	4/5
VT-16/05/2010	0.348	0.36	75.38	76.98	7.34	7.53	4/5	4/5	4	4/5	4/5
VT-20/05/2010	0.57	0.97	75.84	79.34	7	6.9	4/5	4	4	4	4
TE-22/02/2010	0.58	1.91	74.48	79.51	4.97	4.74	4/5	4	4	4	4
TE-17/03/2010	0.78	0.22	82.45	83.32	7.72	7.77	4/5	4	4	4/5	4/5
TE-13/04/2010	0.665	0.43	82.45	83.32	8.43	8.28	4/5	4	4	4/5	4/5
TE-14/05/2010	1.024	0.26	82.45	83.32	5.54	5.44	4/5	4/5	4/5	4	4
TE-17/05/2010	0.23	0.18	75.84	79.34	6.72	6.94	4/5	4/5	4	4/5	4/5
TE-20/05/2010	0.28	0.28	76.56	75.84	6.76	6.88	4/5	4	4	4/5	4/5
Average Value =	0.6505	0.621	76.68	77.972	6.652	6.533	4/5	4	4	4/5	4/5

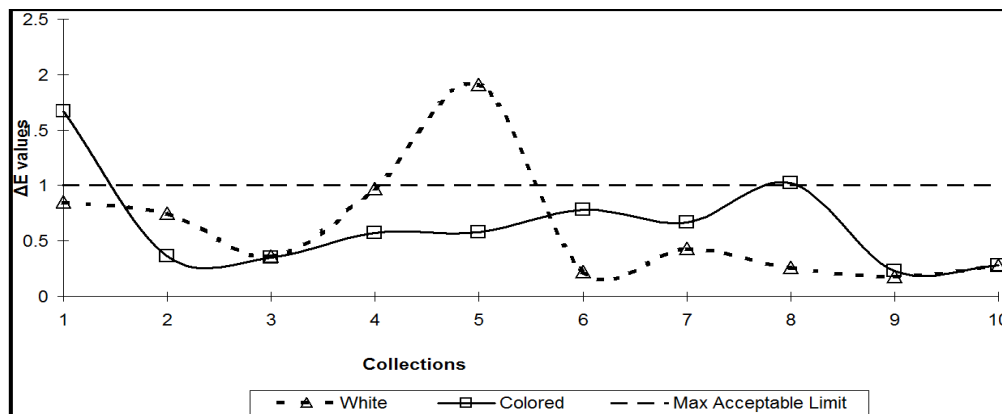


Figure-8: Variation of shade between fresh water and BDR type wastewater treated bleached (white) and dyed (colored) fabric samples.

4.2 DISCUSSION:

Maximum fabric destruction, in terms of weight loss, has found 7% (figure-2) for the wastewater type ASR. Other bleached samples from wastewater have showed lower weight loss than the fresh water treated sample. Hence it can be assume that scouring bleaching with selected wastewater type does not causes more fabric destruction than the same treatment with freshwater. Spot test indicates the absorbency of scoured fabric. In spot test samples, evenly round and well spread dye's drop indicates very good absorbency. In our case wastewater treated samples BDR, EW and AW has shown very good absorbency (figure-7). A comparison of the reflectance of white samples were done to analyze whether the fabric bleached with wastewater get inferior whiteness than the fabric which is bleached with freshwater. For freshwater-bleached white samples, average reflectance has found 77.97% while BDR type of wastewater-bleached fabric samples showed nearly similar whiteness of 76.68% (figure-3, table-2). Least whiteness has found for MW and BFR wastewater-bleached sample which shows reflectance of 68%. The variation of whiteness is determined by measuring the ΔE values between them. CMC ΔE is the indication of shade variation between two samples and is usually measured by the following formula [12]-

$$\Delta E_{CMC} = \sqrt{\left[\left(\frac{\Delta L^*}{l \times S_L} \right)^2 + \left(\frac{\Delta C_{ab}^*}{c \times S_C} \right)^2 + \left(\frac{\Delta H_{ab}^*}{S_H} \right)^2 \right]}$$

Where, ΔL^* , ΔC_{ab}^* , ΔH_{ab}^* , l , S_L , S_C , c and S_H signify their respective values as discussed by Broadbent [12]. $\Delta E > 1$ is not acceptable as it denotes higher difference whereas any value less than 1 is acceptable. Lower the value signify more closer shade. In the present study, all the wastewater-bleached samples showed whiteness difference (ΔE) within acceptable range except wastewater type BFR and MX (figure-3). BDR and ASR samples showed almost similar whiteness having ΔE values only 0.3 and 0.6 respectively (figure-4).

After scouring and bleaching, the samples were dyed with Remazol Red RR reactive dye. The variation of shade between fresh water samples and wastewater treated samples found very negligible. Wastewater type BDR showed excellent shade matching having average ΔE value around 0.5 to 0.6 in most of the cases (figure-8, table-2). Again, the fastness of dyed BDR samples found good to excellent having fastness rating 4 to 5 in colorfastness to wash, rubbing and perspiration (table-2).

Table-2 has summerized all the results for BDR type of wastewater which has found best performing among all the selected wastewater types. Here the wash water samples are collected from different factories at different dates. "Collections" in the charts means the different collection dates and results of each date is the average resulted of tested samples of that particular date. It has been found that fabric samples scoured-bleached with BDR wastewater showed almost similar reflectance in white sample (table-2) in all the collection dates. Beside this, the ΔE values of bleached and dyed samples (fig-8, table-2) has found well below the maximum acceptable range ($\Delta E = 1$) in most of the collections. Again, fabric destruction due to scouring and bleaching action were almost similar to the fresh water treated samples (table-2). From the graph presented in fig-8, it is clearly visible that among ten days trial, average ΔE values of bleached (white) and dyed (colored) fabric are quite acceptable. Hence it can be concluded that BDR type of wastewater can be reused directly without any additional wastewater treatment process for the scouring bleaching purpose of cotton goods with satisfactory scouring-bleaching and dyeing performance.

Now, individual discussion on each type of segregated wastewater stream is given below on the basis of present research study and teste results-

i) Demi. (Demineralization Water):

Demineralization is the first process of cellulose material pretreatment. Water found containing higher amount of loss yarn fragments, external impurities and yellowish in color. Also the reflectance (fig-3) showed least value (68%) in comparison with the other wash water treated sample. The demineralization water is not recommended.

ii) ASR (After Scoured-bleached Rinse): ASR is the rinse water collected from the rinsing bath after draining scouring-bleaching liquor. High weight loss is found (fig-1). Whiteness and shade matching performance is found very good (fig-3,4,5). It can be reused in pretreatment bath of cellulosic fabric with the same chemical recipe as performed. The pH value is slightly higher and the water is not visually very clear like the BDR.

iii) AW (Acid Water, neutralization bath water):

AW is the neutralization bath water collected knitted fabric Dyeing cycle. The fabric sample treated with AW found quite satisfactory for reusing. It is same like BDR and the shade matching performances are also very good. This water can be the perfect alternative for BDR where the knit dyeing factories use dye bath enzyme in the absence of BDR. But, if BDR is available, it is surely preferable than AW.

iv) EW (Enzyme bath water):

EW is quite acidic than the other bath solution and a little objectionable in terms of all general water parameters required for dyeing. It needs further treatment for making this water reusable.

v) EAH (After Enzyme Hot wash water):

EAH is better than direct enzyme bath water. But this water too is not clear enough though showing very good absorbency and whiteness.

vi) BDR (Before Dyeing Rinse):

BDR is the most suitable and highly acceptable than the all other selected wastewaters, due to the presence of very least amount of contamination and very good scouring-bleaching and dyeing performance. It has been found the best performing in respect of visual assessment, water quality analysis, absorbency, weight loss, color difference, shade matching performance and all the fastness tests.

vii) BFR (Before Finish Rinse):

BFR is also the less contaminated as BDR, but it contains faint color after dark shade dyeing (Black, Navy etc). It has been found that required reflectance is not achieved. Thus BFR has been rejected by considering the above cases.

viii) MW (Mixed water):

MW is the even mixture of all less contaminated wash water. MW will provide better result if BFR and Demi water is absent in the mixture. But surely it is not as clear as BDR and also not capable to show the best whiteness and shade.

V. OUTCOME

Based on the results and discussion in the earlier section, it can be summarized that if segregated, selected types of textile wastewater can be reused without any wastewater treatment process. Again, among various segregated wastewater types, before dyeing rinsing (BDR) water from one batch can safely be reused for the scouring bleaching purpose of next batch with satisfactory bleaching and dyeing performance.

VI. CONCLUSION AND RECOMMENDATION

In previous centuries, Less attention was given to the generation of contaminants from the extraction, conversion, supply and use of earth's resources and to the release of these contaminant to the environment [58]. But in this modern era of industrial civilization, it is our soul responsibility to save our beloved earth from being a dead planet by the destruction of its environment. National development and environment is not the opposite side of a coin. The development and prosperity of all nation is directly coupled with the ability to proper utilization, protect and sustain of their water resources [59]. Sustainable development takes place without disruption to the balance of the environment. However, sustainability and zero growth should not be confused. The sustainable development concept focus on the interdependence of environmental safety and economic growth in a society. At one side, natural resources should not be exhausted at the expense of economic growth and on the other side , restrictions should not be set upon the economic activity in the interest of preserving the environment [60]. In common, industrialists do not want to invest in pollution and waste minimization projects as they feel it difficult to allocate their limited technical and financial resources over a heap of pollution and waste control facilities [61]. Hence, reduction of waste generation is a smarter way to control the pollution. According to Young [62] implementation of

a waste minimization program impact the profits immediately and can provide a clear short-term reduction in costs. Effective water management brings a balance in the rate of water withdrawal, use and consumption. Reusing of textile wastewater in the same industry as process water – is a way to minimize the waste generation and to reduce the consumption of natural resource. In general, wastewater from a textile industry needs treatment before reusing it. However this research paper shows that, through segregation it is possible to find out waste streams which can reuse without any treatment. Therefore it is recommended that industrialist should investigate acceptable levels of their own rinsing water to be used as process water. Once the required quality of water for the different operation is established, it will be easy to identify, collect and reuse wastewater without the necessity of treatment as shown in this paper.

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