Supporting Information

Characterization and coagulation/flocculation treatment of coloured wastewater of institutional dyeing laboratory

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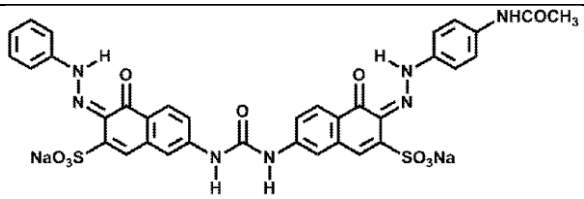
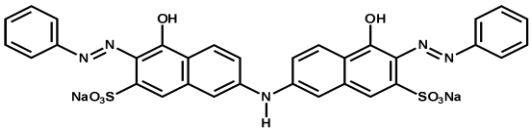
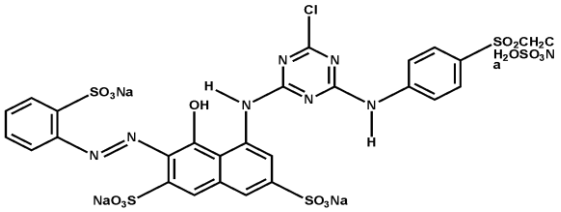
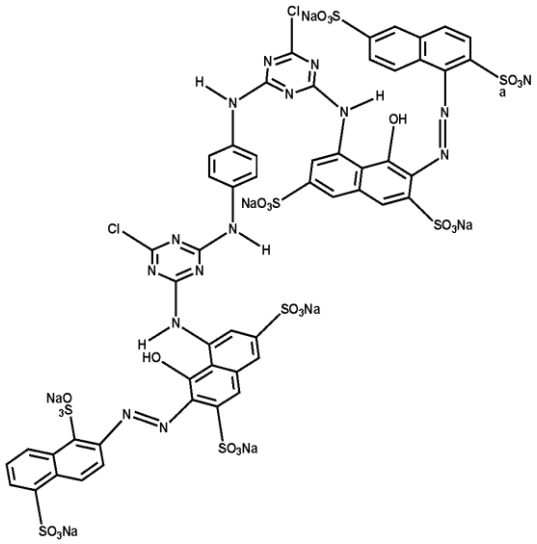
The different dyes used in this study are listed in Table S1. The information about the chemical structure, molecular weight, and wavelength of maximum absorption (λ_{max}) of the dyes were obtained from research papers (cited), otherwise from the e-source, world dye variety.

Table S1: Chemical structures of dyes

Dye	Chemical structure	Molecular weight (g/mol)	λ_{max} (nm)
C.I. Direct Red 23 (C.I. 29160, di-azo)		813.73	504[1]
C. I. Direct Red 31 (C.I. 29100, di-azo)		713.65	525[2]
C.I. Reactive Red 239 (mono-azo)		1136.32	540[3]
C.I. Reactive Red 141 (di-azo)		1774.19	544[4]

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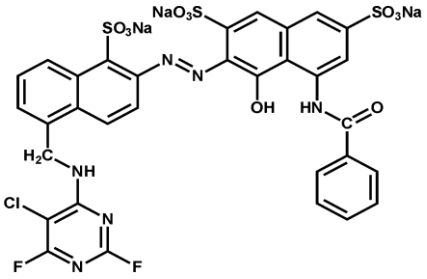
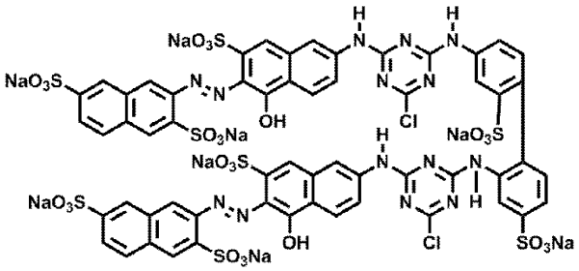
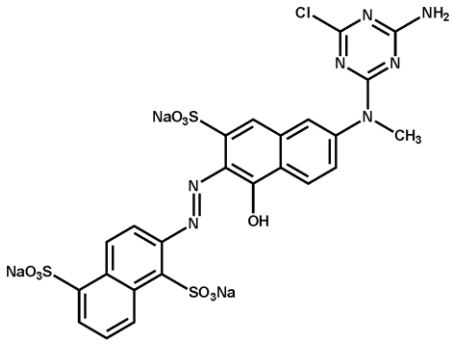
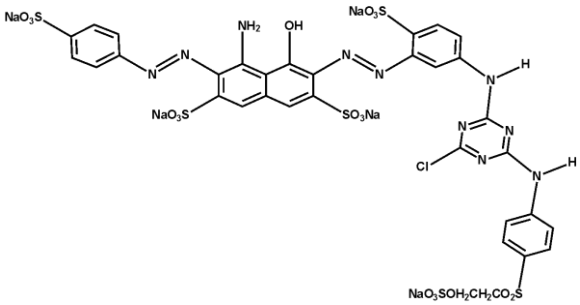
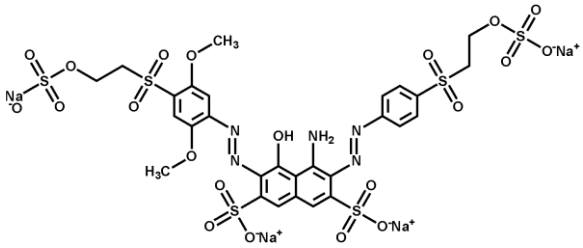
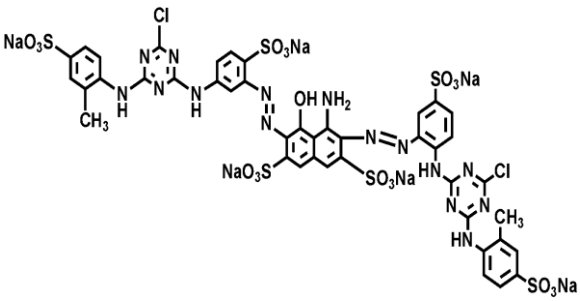
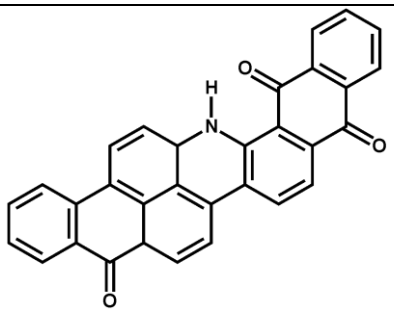
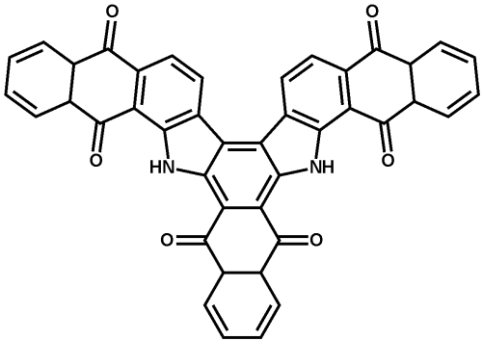
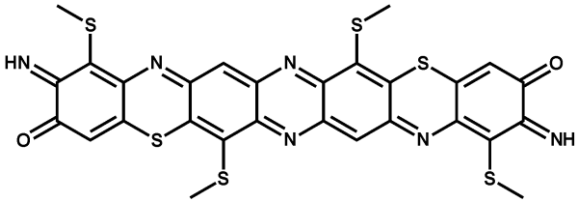
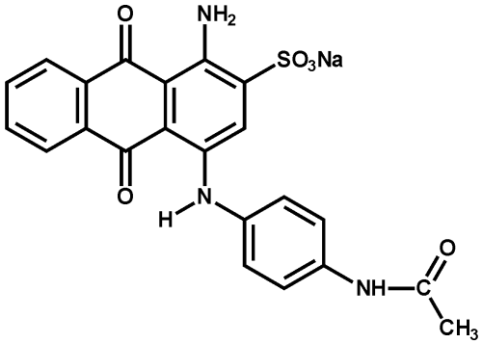
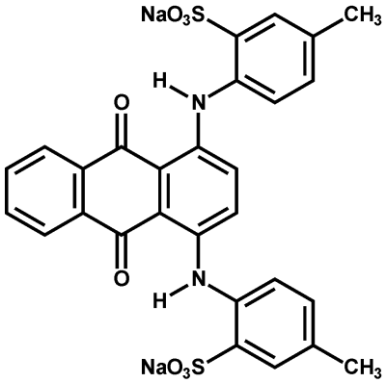
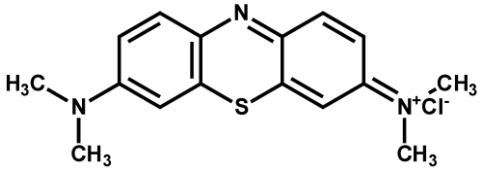
LevafixRed E4BA		-	519[5]
C.I. Reactive Orange 84 (C.I. 292810, di-azo)		1850.29	498[6]
C.I. Reactive Orange 13 (C.I.18270, mono-azo)		762.04	487[7]
LevafixBlue CA	-	-	635[8]
C.I. Reactive Blue 198 (Triphenodioxazine)		1304.80	625[9]
C. I. Reactive Blue 203 (di-azo)		617.54	625[10]
Procion Navy H-EXL (di-azo, mono-chlorotriazine)		-	610[9]

Contd..

C.I. Vat Green 3 (C.I.69500, anthraquinone)		449.46	-
C.I. Vat Brown 1 (C.I.70800, anthraquinone)		646.60	-
Sulphur Black 1 (C.I.53185)		-	-
C.I. Acid Blue 40 (C.I.62125, anthraquinone)		473.43	615[11]
C.I. Acid Green 25 (C.I.61570, anthraquinone)		622.58	642[12]
C.I. Cationic Blue 9 (C.I.52015)		319.85	660[13]

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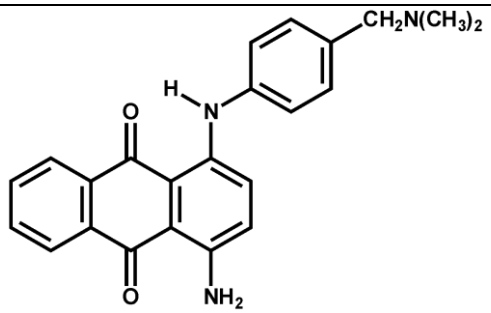
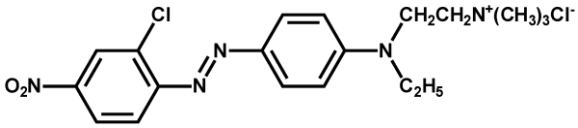
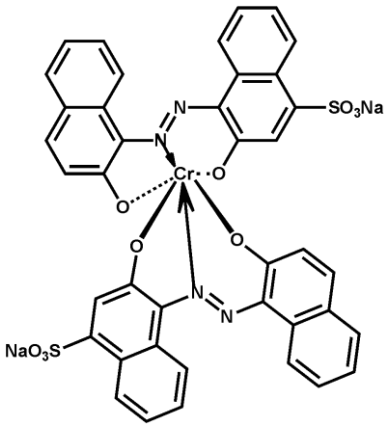
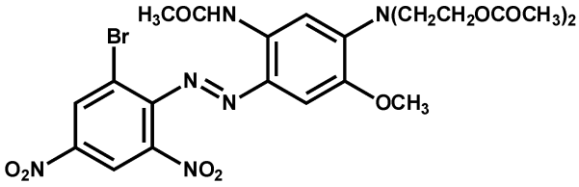
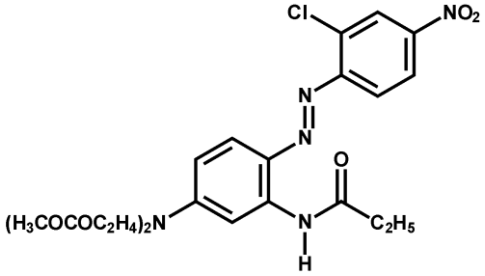
C.I. Cationic Blue 47 (C.I.61111, anthraquinone)		371.43	-
C.I. Cationic Red 18 (C.I.11085, mono-azo)		426.34	480[14]
C.I. Acid Blue 193 (metal complex; MC, 1:2)		-	580[15]
C.I. Acid Red 414 (MC, 1:2)	-	-	-
C.I. Disperse Blue 79.1 (C.I.11344, mono-azo)		625.38	-
C.I. Disperse Red 167 (C.I. 11338, mono-azo)		519.93	-

S2. Dyeing chemicals and textile-auxiliaries

Laboratory grade dyeing chemicals, *viz*. acetic acid (CH_3COOH), sulphuric acid (H_2SO_4), sodium hydroxide (NaOH), sodium carbonate (Na_2CO_3), Glauber's salt ($Na_2CO_3.10H_2O$), sodium sulfate (Na_2SO_4), sodium acetate (CH_3COONa), ammonium sulfate ($(NH_4)_2SO_4$), sodium hydrosulphite ($Na_2S_2O_4$) and sodium sulfide (Na_2S) were procured from S. D. Fine-Chem Ltd., India and used as received. Commercial textileauxiliaries with their trade name and function in dyeing of textiles are listed in Table S2.

Table S2: Textile-auxiliaries used in dyeing of textile fabrics

Trade-name	Function in textile dyeing	Supplier
Hostapal-MRN	Wetting agent	Archroma India Private Limited, Thane, Maharashtra, India
Cbmol-WS	Dispersing agent for disperse dyes	Colorband Dyestuff (P) Ltd., Thane, Maharashtra, India
Dilatin-HT	Carrier in disperse dyeing of polyester	Archroma India Private Limited, Thane, Maharashtra, India
Saragen-KDF	Leveling agent indyeing of synthetic fiber based fabrics and their blends	Sarex Chemicals. Mumbai, Maharashtra, India
Defoamer-DMS	Defoaming agent	Swissol Organics Pvt. Ltd., Mumbai, Maharashtra, India
Auxipon-NP	Non-ionic detergent	Auxichem, Navi-Mumbai, Maharashtra, India

S3. Fabrics

The dyeing grade (i.e. scoured and bleached) natural and synthetic fiber based fabrics were used as received, and their specifications are summarized in Table S3.

Table S3: Natural and synthetic fiber fabrics

Fabric	Fabric-specification and supplier
Cotton	Plain weave, 80 g/m^2, Swadeshi Dyeing and Bleaching Mills, Ichalkaranji, Maharashtra, India
Wool	Twill weave, 180 g/m^2, Raymond Ltd., Vapi, Gujarat, India
Silk	Plain weave, 90 g/m^2, Jharcraft, Ranchi, Jharkhand, India
Polyester	Plain weave, 70 g/m^2, Piyush Syndicate, Mumbai, Maharashtra, India
Nylon	Knitted, 300 g/m^2, Piyush Syndicate, Mumbai, Maharashtra, India
Acrylic	Knitted, 260 g/m2, Piyush Syndicate, Mumbai, Maharashtra, India

S4. Dyeing procedure

In all the dyeing experiments, 2 g fabric sample (pre-wetted with water, otherwise, mentioned specifically) were used. Liquor ratio (LR) of 50 and temperature gradient of 2 °C/min were used throughout the dyeing experiments and after-treatments such as soaping or reduction clearing.Except polyester fabric, both dyeing and after-treatments of all other fabric samples were performed on the digital open water-bath dyeing machine (6 pots, JK & PC Texlab Equipments, Mumbai, Maharashtra, India). Dyeing of polyester fabric samples with dispersed dyes was performed on high-temperature (HT) sample dyeing machine (12 pots, R. B. Electronics and Engineering Pvt. Ltd., Mumbai, Maharashtra, India). The standard procedures for making the stock dye solution (1%, w/v, 20 mL) and dyeing of fabric samples with different dyes are briefed as below.

S4.1. Dyeing of cotton with direct dyes

Pre-requisite amount of direct dye was mixed with a pinch of Na_2CO_3 and a small amount of warm water (40-50 °C) to obtain a clear dye solution, and later diluted up to the required volume using hot water (>60 °C). The dye bath was prepared with required volume of direct dye solution and water. Cotton fabric was immersed into the dye bath at room temperature. After 15 min of commencement of dyeing, Glauber's salt (20%, on the weight of fabric, owf) was added in the dye bath and temperature

of dye bath was raised to 90 °C. Dyeing was continued at 90 °C for 60 min. Finally, the dyed sample was rinsed with cold and hot water, and dried at room temperature.

S4.2. Dyeing of cotton with reactive dyes

Reactive dyes have been classified into different classes depending on reactive groups present in the dye molecules. The protocols for preparing the stock dye solution (1%, w/v) and washing treatment (after dyeing), using non-ionic detergent (Auxipon-NP, 2 g/L, 20 min, 80 °C) were similar for all the class of reactive dyes. The stock dye solution (1% w/v, neutral pH), was prepared by dissolving the required amount of reactive dye with warm water (40-45 °C). The dyeing procedure for cotton fabric samples with different class of reactive dyes is as follows.

S4.2.1. Cold brand reactive dyes

Dyeing was initiated at room temperature by immersing the cotton fabric samples into the dye bath and dyeing was continued for 15 min. Then Glauber's salt (15-30 g/L) was added into the dye bath and dyeing continued for 30 min. Na_2CO_3 (15-30 g/L) was then added and dyeing was continued for 45 min. After this, the fabric sample was removed from the dye bath, rinsed with cold and hot water, and washed with non-ionic detergent. Finally, the dyed fabric sample was rinsed with hot and cold water, and dried at room temperature.

S4.2.2. Hot brand reactive dyes

The dye bath was set with the required quantity of dye solution and the cotton fabric was entered into the dye bath at room temperature. After 15 min of commencement of dyeing, Glauber's salt (40-60 g/L) was added into the dye bath in two installments and temperature of dye bath was raised up to 80 °C. Dyeing was continued for 45 min at 80 °C and then Na_2CO_3 (10-20 g/L) was added and dyeing was further continued for 45 min. Finally, reactive dyed fabric was washed and dried.

S4.2.3. Vinyl sulphone reactive dyes

The cotton fabric was immersed into dye bath at room temperature and after 15 min of commencement of dyeing, Glauber's salt (30-60 g/L) was added and temperature of dye bath was raised to 65 °C. Dyeing was continued for 45 min and then Na_2CO_3 (10-20 g/L) was added into the dye bath and dyeing was continued for another 45 min. Finally, the dyed fabric was washed and dried.

S4.2.4. Bi-functional reactive dyes (ME and HE reactive dyes) The dyeing procedure for ME and HE class of reactive dyes was the same as that of vinyl sulphone and hot brand reactive dyes, respectively.

S4.3. Dyeing of cotton with vat dyes

The required amount of vat dye was weighed and pasted with a little amount of wetting agent, Hostapal-MRN and then hot water (>60 °C). Then NaOH (twice to weight of dye) and $Na_2S_2O_4$ (1.5 times weight of dye) were added and solubilization of dye i.e. vatting was carried out at 60 °C till complete reduction of dye was achieved (confirmed by clear spreading of dye solution drop on filter paper). Finally, the vat dye solution was diluted with hot water up to the required volume. The dye bath was set up with the required quantity of reduced dye solution, water, NaOH (15 g/L), $Na_2S_2O_4$ (10 g/L), and Glauber's salt (10 g/L). Cotton fabric (pre-wetted with a solution of NaOH and $Na_2S_2O_4$) was immersed into the dye bath at room temperature. Dyeing was performed at room temperature for 15 min and then temperature of the dye bath was raised to 50 °C and dyeing was additionally carried out for 30 min. The alkaline reducing condition of the dye bath during the complete dyeing cycle was periodically confirmed using phenolphthalein (turns to pink in alkaline pH) and yellow vat paper (turns to blue in presence of reducing agent), respectively. After dyeing, the

dyed fabric was gently rinsed with cold water and air oxidized for 5 min for converting the reduced dye into its insoluble form. Finally, the dyed fabric was washed using non-ionic detergent and Na_2CO_3 (2 g/L, each, 20 min, 80 °C), rinsed with hot and cold water and dried.

S4.4. Dyeing of cotton with sulfur black dye

The required amount of sulfur dye was weighed and pasted with Hostapal-MRN (wetting agent). Then Na_2CO_3 (equal to the weight of dye) and Na_2S (1.5 times the weight of dye) were mixed with the sulfur dye and hot water. The mixture was heated to about 80 °C for 15 min to obtain a clear dye solution and diluted up to required volume using hot water. The dye bath with alkaline reducing conditions (Na_2CO_3 and Na_2S, 15 g/L, each) was set up at 50 °C with the required amount of dye solution. Then cotton fabric pre-wetted with a solution of Na_2CO_3 and Na_2S (10 g/L, each) was immersed in the dye bath. After 15 min of commencement of dyeing, temperature of dye bath was increased to 90 °C and Glauber's salt (20% owf) was added and dyeing was continued for an additional 60 min. Then the dyed fabric was removed from the dye bath, rinsed with cold water and air-oxidized for 5 min to convert the solubilized sulfur dye in its parent insoluble form. Finally, the sulfur dyed fabric was washed as that of vat dyed fabric and dried.

S4.5. Dyeing of wool, silk and nylon with acid dyes

The required amount of acid dye was weighed and pasted with 1-2 drops of CH_3COOH, solubilized and diluted up to the required volume using hot water (60 °C). The dye bath was set up at room temperature with the required quantity of acid dye solution, H_2SO_4 (3% owf) and Glauber's salt (20% owf, except for nylon dyeing). Fabric samples were immersed in the dye bath and after 15 min of dyeing, temperature of the dye bath was increased to 80 °C for silk, and 90-95 °C for wool and nylon. Dyeing was continued at these temperatures for 45 min, wherein, CH_3COONa (3% owf, buffer) was also added in the dye bath after 20 min of dyeing at elevated temperature. Finally, the dyed fabrics were thoroughly rinsed with tap water, squeezed and dried at room temperature.

S4.6. Dyeing of wool with MC dyes

The MC dye (1:2) solution was prepared in the manner like that of acid dye solutions. The dye bath was set up with the required quantity of dye solution, $(NH_4)_2SO_4$ and CH_3COOH (4% owf, each). Wool fabric samples were immersed in the dye bath at room temperature and dyeing was performed for 15 min. Then the temperature of the dye bath was increased to 90-95 °C and dyeing continued for 45 min. After dyeing, the fabric was removed from the dye bath, rinsed thoroughly with tap water and dried at room temperature.

S4.7. Dyeing of wool, silk and acrylic with cationic (basic) dyes

The required amount of basic dye was weighed, pasted with 2-3 drops of CH_3COOH, solubilized and diluted up to the required volume using hot water (60 °C). The dye bath was set up with CH_3COOH and CH_3COONa (3% owf, each) and dyeing was commenced by immersing the fabric samples (wool and silk) in the dye bath at room temperature. Then the temperature of the dye bath was raised to 90 °C and dyeing continued for 45 min. Finally, the fabric was removed from the dye bath, rinsed with cold water and dried at room temperature. In case of acrylic fabric samples, same dyeing procedure was followed, with the exception that the leveling agent (Saragen-KDF, 1 g/L) was also added in the dye bath along with other reagents.

S4.8. Dyeing of polyester fabric with disperse dyes

S4.8.1. Carrier dyeing method

The aqueous dispersion of dispersed dye was prepared by dispersing the required amount of dispersed dye and dispersing agent (Cbmol-WS, 0.5 g/L), CH_3COOH (0.5 g/L, for adjusting the pH of dye solution, 5-6). The dye bath was set up in an air-tight stainless steel dyeing pots with required quantity of disperse dye solution, leveling agent (Saragen-KDF, 0.5 g/L), carrier (Dilatin-HT, 2 g/L) and CH_3COOH (1 g/L, pH = 4.5-5.5) and polyester fabric samples. The dyeing was commenced at room temperature in the HTHP dyeing machine and after 5 min of commencement of dyeing, temperature of dye bath was increased to 100 °C and dyeing was continued for 1 h at this temperature. Then the dye bath was cooled to 40 °C, dyed polyester fabric samples were removed from the dye pot and rinsed thoroughly with hot water. Then the dyed polyester fabric samples were subjected to reduction cleared using NaOH and $Na_2S_2O_4$ (2 g/L each, 60 °C for 20 min). Finally, the samples were rinsed thoroughly with excess hot water, neutralized with CH_3COOH (1 g/L), and dried at room temperature.

S4.8.2. High temperature (HT) dyeing method

In this method, the dye bath was prepared in a similar manner as that of the carrier dyeing method of polyester using disperse dyes; wherein, addition of carrier in the dye bath was an exception. After 5 min of commencement of disperse dyeing of polyester the temperature of dye bath was increased to 130 °C and dyeing was continued for 60 min. Then the dye bath was cooled down to 40 °C and dyed polyester fabric samples were subjected to reduction clearing treatment as mentioned in section, S4.8.1, neutralized, rinsed with hot and cold water and dried at room temperature.

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