Universal Journal of Environmental Research and Technology
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Available Online at: www.environmentaljournal.org
Volume 2, Issue 5: 421-428

Open Access **Research Article**

Investigation on Ecological Parameters of Dyeing Organic Cotton Knitted Fabrics

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Abstract:

In this study, the ecological parameters of the effluent obtained from dyeing of scoured and mercerised organic cotton single jersey fabrics with textile reactive dyes adopting exhaust dyeing method was investigated. The dyes used include regular (Navacron H and FN) reactive dyes and low impact (Remazol and Levafix) reactive dyes along with inorganic salt (sodium sulphate) and biosalt (trisodium citrate). The ecological parameters include chemical oxygen demand (COD), biological oxygen demand (BOD) and total dossolved solids (TDS). The results show that the use of the low impact reactive dyes has greater ecological advantages as it reduces the COD, BOD and TDS of the effluent considerably. Further, the use of the biosalt in the dye bath as replacement for the inorganic salt reduces the COD and TDS value significantly but will also increase the BOD of the effluent.

Keywords: Organic cotton, Knitted fabrics, Textile dyes, Dyeing, Ecological aspects

1.0 Introduction:

The textile industry actually represents a range of industries with operations and processes as diverse as its products (Jayanth et al, 2011; Sajjala et al, 2008). Gary fabrics, after its manufacturing, are subjected to several wet processes such as pretreatment process involving demineralization, scouring, bleaching and mercerisation. The pretreated fabric is then dyed using textile dyes and finished by softener padding. The pretreament and dyeing process results in large volume of effleunt that has harmful effect on environment (Correia et al 1994; Desai & Kore, 2011; Sofia et al, 2000; Sajjad & Amna, 2011; Joshi & Santani, 2012; Lav & Jyoti, 2011; Sivakumar. et. al, 2011, Ramesh et al, 2007; Sengupta, 2007; Tufekci et al, 2007; Bisschops & Spanjers, 2003; Imtiazuddin et al, 2012). The high volume of effluent is primarly due to large volume of water and chemicals used during wet processing. The chemicals used in textile sector are diverse in chemical composition ranging from inorganic to organic. Generally, textile effluent is colored with high pH, temperature, biological oxygen demand (BOD), chemical oxygen demand (COD), total dissolve solid (TDS) and total suspended solid (TSS). Color is imparted to textile effluents because of the various dyes and pigments used to color the fabric. The presence of dyes in the waste waters will cause severe damage to the aquatic biology. This is because dyes have a synthetic origin and a complex molecular structure which makes them more stable and difficult to be biodegraded (Noor & Rohasliney, 2011).

Since textile processing operation uses a number of organic and inorganic chemicals along with large volume of water, an essential and often difficult step in pollution prevention is to accurately and realistically assess the current status of mill and its potential for improvement. This assessment is necessary to target specific waste streams that will maximize pollution prevention. The first step in a pollution prevention strategy is a thorough audit and characterization of wastewater from textile operations. Comparing the information from this audit with benchmark data allows for realistic goal setting and economic projections for pollution reduction activities.

Several options exist for benchmarking an operation and, hence, for identifying pollution prevention targets (Nese et al, 2007; Datta, 2011; NRDC, 2010). These include redesigning of processes, chemical alternatives, substitutions, new technologies and good house keeping (RAC/CP, 2002). Application of known technologies based on documented studies often produces great benefits, however, accurate information about the pollution potential of various processes and products are needed, to ensure optimal results (Brent, 1994). Keeping in view the significance of pollution from the processing, the present work has been undertaken to investigate the ecological parameters of effluent obtained from dyeing the organic cotton single jersey knitted fabric with the regular and low impact reactive dyes. The effluent parameters studied includes COD, BOD and TDS.

2.0 Methodology:

2.1 Dyeing Organic Cotton Knitted Fabrics

For the study, 10 colours were selected for dyeing using the scoured and mercerised ready for dyeing (RFD) cotton knitted fabrics. The colours include yellow, stone, dark violet, brown, maroon, torquoise blue, dark green, red, dark blue and black. The selected samples were sent to a dyeing mill to obtain the dye recipe. The recipe obtained was based on Navacron H and FN reactive dyes, inorganic salt and alkali. The combination is termed as regular reactive dyes throughout the study. Further, the selected samples were sent to Dystar, Tirupur to obtain recipe based on low impact reactive dyes such as Remazol, Remazol ultra RGB and Levafix CA series of dyes. This combination is termed as low impact reactive dyes throughout this study. The Navacron H & FN reactive dyes were obtained from the Huntsman Textile Effects distributor, Bangalore and Remazol, Levafix reactive dyes were obtained from the Dystar distributor, Tirupur. The lab dyeing trails were done using HTHP lab dyeing machine with 10 gm scoured and mercerised organic cotton RFD knitted fabric samples.

Three different dyeing methods were adopted. These include dyeing method P1 that uses regular reactive dyes, salt and alkali. Here, Navacron brand reactive dyes were used for dyeing using exhaust dyeing method. Dyeing method P2 uses regular reactive dyes, biosalt and alkali. Here the dyes and auxiliary chemicals are similar to that used in P1 dyeing process, except that biosalt trisodium citrate is used as exhausting agent instead of inorganic salt. Dyeing method P3 uses low impact reactive dyes, salt and alkali. Here Remazol and Levafix series of low impact reactive dyes was used for dyeing fabric with exhaust dyeing method. The recipe for dyeing is presented in Tables 1 & 2. Auxiliary chemicals like wetting agent (albaflow CIR), lubercating agent (albafluid C) and dyebath stabilizer (albatex DBC) were used in all dyeing method. During the lab dyeing process, effluent from dyeing, soaping and rinsing process was collected and analysed for ecological parameters such as Chemical Oxygen Demand (COD), Biological Oxygen Demand (BOD) and Total Dissolved Solids (TDS).

2.2 Ecological Parameters of Dyeing Processes:

2.2.1 Chemical Oxygen Demand (COD)

The COD is used as a measure of oxygen equivalent of organic matter content of sample that is susceptible to oxidation by strong chemical oxidant for sample from a specific source. To determine COD of the effluent, the sample was first shaken well to mix the contents thoroughly. 10 ml of the sample was placed in a reflex tube.To this, mercuric sulphate ($HgSO_4$) was added according to the chloride concentration to dissolve $HgSO_4$. A pinch of (silver sulfate) $AgSO_4$ was added followed by addition of 30ml of conc. H_2SO_4 along the sides and the mixture was cooled. 10ml of potassium dichromate ($K_2Cr_2O_7$) (0.25N) solution was pipetted out into the flask and mixed well. The flux tube was placed in reflux apparatus with the condenser.The open end of condenser was covered with a small beaker to prevent foreign material from entering refluxing mixture. The mixture was refluxed for 2 hours at around 150°C temperature. After 2 hours, the flask was cooled and 80ml-distilled water was added. The final volume of the mixture in the tube will be around 140 ml. It was cooled to room temperature and then titrated against the ferrous ammonium sulphate (FAS) (0.1N) using 2-3 drops ferroin indicator. The end point of the titration was the first sharp colour changes from blue green to reddish brown. In the same manner a blank solution containing the reagents and 20 ml of distilled water was refluxed and titrated. The final volume was made to 140ml. The COD (mg O_2 / l) value was obtained using the formula shown below:

$$= ((A - B) \times \text{FAS normality} \times 8 \times 1000) / (\text{sample (ml)})$$

Where, A = volume of FAS consumed for reagents blank, B = volume of FAS consumed for sample

2.2.2 Biological Oxygen Demand (BOD)

The BOD is a measure of the quantity of oxygen used by microorganisms in the oxidation of organic matter. The basic principle involves the estimation of dissolved oxygen uptake of sample and blank initally and after incubation for 3 days at 27^{0}C.

Table 1: Dye bath recipes for dyeing with the regular and low impact reactive dyes

Sample	Colour	Regular (P1) / Biosalt (P2) dyeing process		Low impact (P3) dyeing process	
		Dye	Qty (gpl)	Dye	Qty (gpl)
1	Yellow	Navacron Yellow FN2R	0.21	Levafix Brill Yellow CA	0.419
		Navacron Blue FNR	0.04	Levafix orange CA	0.0572
				Levafix Blue CA	0.0245
2	Stone	Navacron Yellow FN2R	0.10	Remazol Yellow RR	0.118
		Navacron Red FN2BL	0.18	Remazol ultra caramine RGB	0.05
		Navacron Blue CD	0.13	Remazol Blue RR	0.0876
3	D Violet	Navacron Yellow S3R	0.70	Remazol ultra yellow RGB	0.498
		Navacron Ruby S3B	0.70	Remazol ultra caramine RGB	0.52
		Navacron Blue FNR	1.18	Remazol Blue RGB	1.06
4	Brown	Navacron Yellow S3R	0.66	Remazol yellow RR	0.933
		Navacron Red FN2BL	0.75	Remazol ultra caramine RGB	0.295
		Navacron Blue FNR	0.52	Remazol Blue RR	0.53
5	Maroon	Navacron Yellow HRN	1.85	Remazol ultra yellow RGBN	3.00
		Navacron Red HB	4.27	Remazol ultra Red	3.80
		Navacron Navy H2G	1.00	Remazol Navy RGB	2.15
6	T Blue	Navacron Yellow HRN	0.21	Remazol Yellow 3GL	0.05
		Navacron Blue HRN	2.30	Remazol T Blue G133	1.50
		Navacron T Blue	0.45	Remazol Blue RGB	0.80
7	D Green	Navacron Yellow HRN	0.90	Remazol yellow 3GL	1.00
		Navacron Blue HRN	1.10	Remazol T Blue G133	2.30
		Navacron T Blue	4.00	Levafix Blue CA	0.20
8	R Blue	Navacron Yellow HRN	0.63	Remazol ultra yellow RGBN	0.60
		Navacron Red HB	1.07	Remazol Ultra Red RGB	1.25
		Navacron Navy H2G	5.30	Remazol Navy RGB	2.50
9	Red	Navacron Yellow HRN	1.20	Remazol Ultra yellow RGBN	2.20
		Navacron Red HB	3.85	Remazol Ultra Red RGB	4.50
		Navacron Blue HRN	0.207	Levafix Blue CA	0.25
10	Black	Navacron Black G	3.42	Remazol Deep Black RGBN	9.00
		Navacron Black R	4.30		

Table 2: Dyebath chemicals (gpl) used in regular dyeing, biosalt and low impact dyeing process

Sample	Colour	Dye quantity	Salt & soda process (P1)		Biosalt & soda (P2) process		Low impact (P3) dye process			
			Salt	Soda	Biosalt	Soda	Dye quantity	Salt	Soda	Caustic soda flakes
1	Yellow	0.250	20	7.50	6.67	7.50	0.501	20.00	6	-
2	Stone	0.405	20	7.50	6.67	7.50	0.260	12.50	5	-
3	D Violet	2.580	40	12.50	13.33	12.5	2.077	40.00	10	-
4	Brown	1.930	30	10.00	10.00	10.0	1.758	35.00	9	-
5	Maroon	7.120	80	20.00	26.67	20.0	8.950	100.00	5	2.60
6	T Blue	2.960	80	20.00	26.67	20.0	2.350	55.00	5	1.00
7	D Green	6.000	80	20.00	26.67	20.0	3.450	65.00	5	1.50
8	R Blue	7.000	80	20.00	26.67	20.0	4.350	80.00	5	1.84
9	Red	5.257	80	20.00	26.67	20.0	6.950	100.00	5	2.60
10	Black	7.720	80	20.00	26.67	20.0	9.000	100.00	5	2.60

To determine the BOD, the sample was taken adequately in 300 ml BOD bottles and was filled with dilution water. The bottle was incubated at 27°C for 3 days. 2 ml manganese sulfate ($MnSO_4$) solution and 2 ml of alkali iodiedazide solution are added in another bottle.The stopper was put and the bottle was inverted a few times to mix the contents. The precipitate was allowed to settle to leave clear supernatant above the brown colour manganese oxi hydroxide floc.The stopper was carefully removed and 2ml concentrated sulphuric acid (H_2SO_4) was added by the sides of the bottle.The stopper was put and the solution was mixed by inverting the bottle several times until it dissolves completely. 200 ml of the solution was taken from the bottle and was titrated against 0.025 N. sodium thiosulphate ($Na_2S_2O_3$) solution to a pale yellow colour. Few drops of starch indicator are added and titration was continued till the change of blue colour to colour less was observed. For blank solution, the same procedure was followed by taking 300ml dilution water without sample to estimate 0 day dissolved oxygen. After 3 days incubation, the same procedure was repeated to estimate 3rd day dissolved oxygen. The final BOD (mg O_2 / l) value was determined using the formula:

$$= (((D1 - D2) - (B1 - B2)) \times f) / P$$

Where, D1= initial dissolved oxygen in sample, D2= sample dissolved oxygen after 3 days incubation, B1= initial dissolved oxygen in blank, B2= blank dissolved oxygen after 3 days incubation, P= decimal volumetric fraction of sample used, f= ratio of seed in diluted sample to seed in blank.

2.2.3 Total dissolved solids (TDS)

TDS is a measure of the combined content of all inorganic and organic substances contained in a liquid in molecular, ionized or micro-granular suspended form. The TDS of the samples were determined by gravimetric method that involved evaporating the liquid solvent to leave a residue that can subsequently be weighed with a precision analytical balance (normally capable of 0.0001 gram accuracy). The TDS (mg/l) in the effluent was determined as per the formula given below.

$$= ((A - B) \times 1000 \times 1000)/\text{Sample volume}$$

Where, A= final weight of the dish with sample residue, B=initial weight of the dish (empty dish).

3.0 Results and Discussions:

3.1 Chemical Oxygen Demand

The COD (mg O_2/l) values of the effluent for dyeing of the scoured and mercerised fabrics are presented in Figure 1. The results show that the COD of the effluent does not show much difference between three methods of dyeing for the light colours whereas it varies for the dark colours. Further, the COD of the effluent for dyeing of fabrics with light colours is less compared to that of dark colours. This is because the development of light colour requires less quantity of dyes and dye bath chemicals/auxillaries compared to dark colours.

The COD of the effluent for the dyeing process P1 with the dark colours for scoured fabrics show higher value compared to other two methods. The COD of the dyebath effluent for the mercerised fabrics also follows the same trend. In case of dyeing scoured fabrics, the COD of the effluent for the dyeing process P3 that uses the low impact reactive dyes with salt and soda is less compared to the P1 dyeing method whereas it varies when compared with P2 dyeing process. Similarly, for dyeing mercerised fabrics, the COD of dye bath effluent from P3 dyeing process is less compared to other two methods.

In general, it is observed that COD of the effluent obtained from the dyeing of the scoured fabrics with P2 and P3 dyeing process is 15.24% and 14.98% less compared to that of the effluent obtained from the dyeing method P1. Similarly in case of the mercerised fabrics, the COD of the effluent from P2 and P3 dyeing process is 6.23% and 17.33% less compared to that of the P1 dyeing process. Hence, it can be concluded that the dyeing of fabric with the low impact dyes can reduce the COD of the effluent to a considerable extent as compared to that of dyeing with the regular dyes using inorganic or biosalt.

3.2 Biological Oxygen demand

The BOD (mg O_2/l) values for dyeing process of the scoured and mercerised fabrics are presented in Figure 2. The results show that the BOD of the dyebath effluent for the dyeing process P3 with low impact reactive dyes is less compared to the P1 & P2 dyeing methods for both the scoured and mercerised fabrics. When the BOD of effluent for the dyeing process P1 & P2 is compared, effluent of the P2 dyeing process show slightly higher BOD values compared to the P1 dyeing process. Hence, it can be concluded that dyeing of the fabric with the low impact reactive dyes can reduce the BOD of effluent to a large extent as compared to the dyeing process with the regular dyes using inorganic or biosalt.

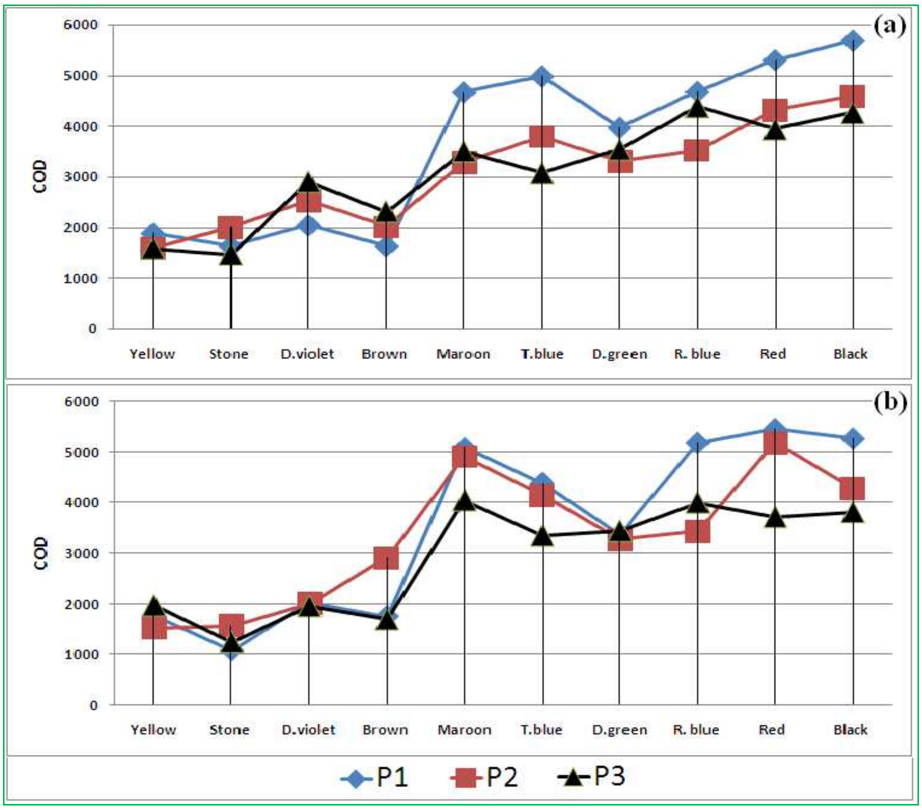

Figure 1: Comparsion of COD (mg O_2/l) values for regular (P1), biosalt (P2) and low impact (P3) dyeing process effluents for scoured (a) and mercerised (b) fabrics

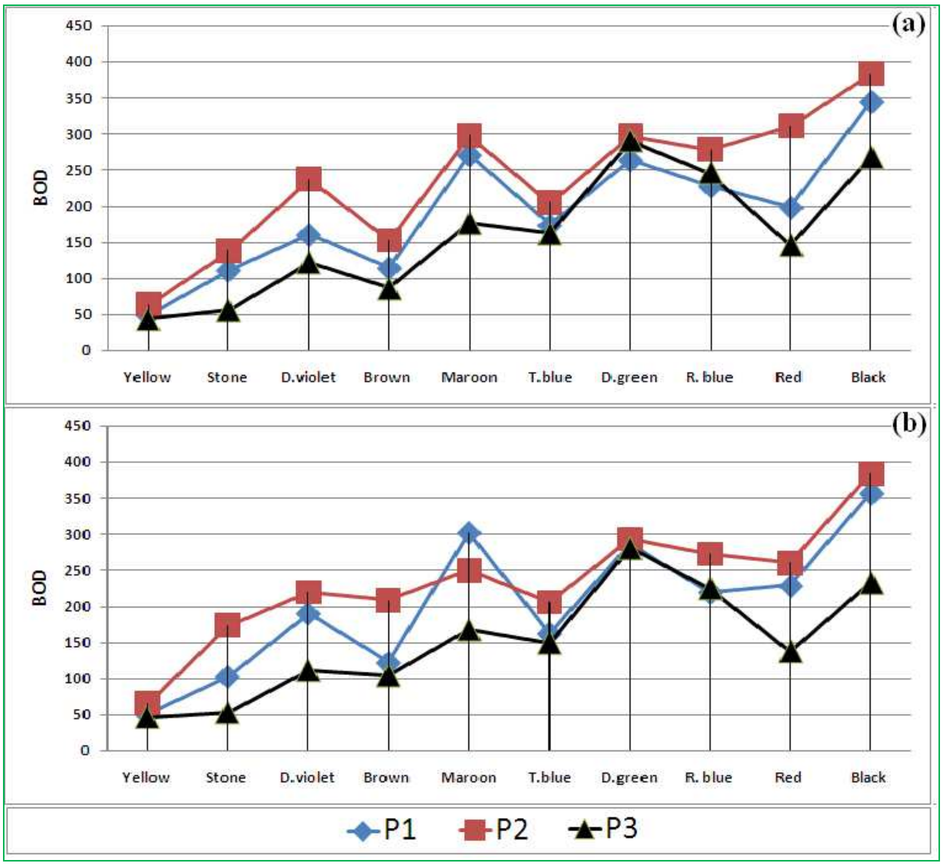

Figure 2: Comparsion of BOD (mg O_2/l) values for regular (P1), biosalt (P2) and low impact (P3) dyeing process effluents for scoured (a) and mercerised (b) fabrics

In general, the BOD of the dyebath effluent from the dyeing process P2 with the regular dye using biosalt is 23.84% and 15.42% more compared to that of the dyeing process P1 with the regular dye and inorganic salt for the scoured and mercerised fabrics. Similarly, the BOD value of the dyebath effluent obtained from the use of the low impact dyes for the dyeing process P3 is 16.32% and 25.39% less compared to that of the dyebath effluent from P1 dyeing process with the regular dyes for the scoured and mercerised fabrics.

3.3 Total Dissolved Solids

The TDS (mg/l) values for the dyeing of the scoured and mercerised fabrics are presented in Figure 3. The results show that the TDS of the effluent obtained from the dyeing of the scoured and mercerised fabrics to light colour is less compared to that of dark colours. This is due to low quantity of inorganic chemicals used in the dyeing process to obtain light colours. The TDS of the dyeing effluent for dyeing mercerised fabrics to dark colours follows the same trend as that of the scoured fabrics but with different values.

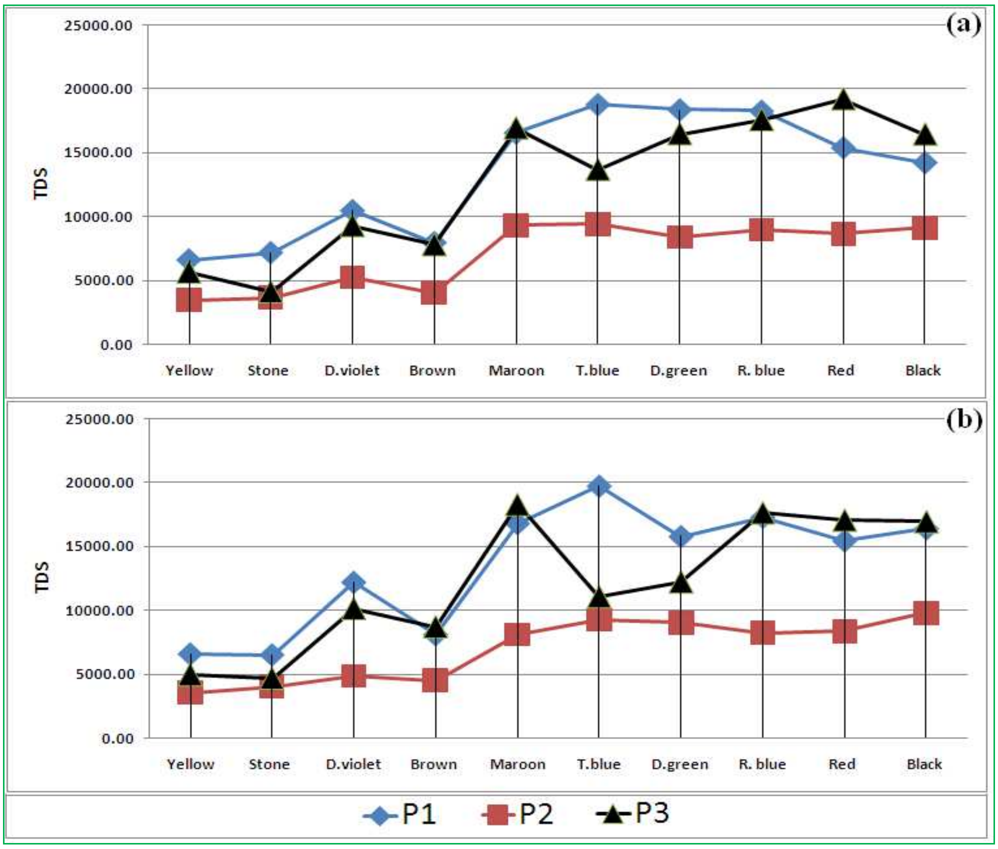

Figure 3: Comparsion of TDS (mg/l) values for regular (P1), biosalt (P2) and low impact (P3) dyeing process effluents for scoured (a) and mercerised (b) fabrics

Further, it is observed that the TDS of the dyebath effluent from the dyeing process P2 with the biosalt is reduced considerably. This is because of less quantity of biosalt trisodium citrate used in the P2 dyeing process compared to that of the inorganic salt sodium sulphate used in P1 & P3 dyeing process. The quantity of biosalt used is less because one molecule of trisodium citrate consists of 3 sodium atoms. In case of the dyeing with low impact dyes for both scoured and mercerised fabrics, the TDS of the dyebath effluent is slightly less compared to effluent from dyeing process P1 for light colours whereas it varies for dark colour.

In general, it is observed that TDS of the effluent obtained from the dyeing of the scoured fabrics with P2 and P3 dyeing process is 47.43% and 4.83% less compared to that of the effluent obtained from the dyeing method P1. Similarly in case of the mercerised fabrics, the TDS of the effluent from P2 and P3 dyeing process is 48.32% and 9.78% less compared to that of the P1 dyeing process. Hence, it can be concluded that the dyeing of fabric with the low impact dyes can reduce the TDS of the effluent to a slight extent when compared to that of dyeing with the regular dyes using inorganic salt, whereas, the TDS will reduce drastically when dyeing is done using biosalt.

4.0 Conclusions:

In general, the results show that the use of the low impact reactive dyes has greater ecological advantages as it reduces the COD, BOD and TDS of the effluent considerably. Further, the use of the biosalt in the dye bath as replacement for the inorganic salt reduces the COD and TDS value significantly but will increase the BOD of the effluent to a greater extent.

5.0 Acknowledgements:

The authors would like to thank Mr. M. B. Ambruthesh, Senior Exective, Indusfila Limited, Nanjangud, Mysore, India for all the cooperation during this work.

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