WATER REUSE IN THE TEXTILE INDUSTRY'S DYEING PROCESS

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ABSTRACT - Textile industries produce a great amount of water retrieved from processed material, with a very high production of liquid effluents and pollution charge. Current analysis demonstrates the viability of direct reuse of the liquid flow of textile effluents from the dyeing process of cloth made of 100% PES (Polyester), 100% PES/PUE (Polyester with elastane) and 100% PA (Polyamide). This fact implies tolerance limits for the approval of dyed substrate tonality as a variation of tonality (ΔE), tissue solidity test and pH in dyeing baths. All types of dyeing and analyses were performed at a laboratory scale in a textile industry in Joinville SC Brazil. A 75% saving in auxiliary dyeing products occurred, coupled to a 40% decrease of effluent that would be used in the liquid treatment process.

1. INTRODUCTION

Globalization has caused many firms to modernize their installations and become more competitive. However, an increase in industrial demands brought about a scarcity in natural resources, coupled to strict environmental laws in industrialized countries and short and long term urgent adaptation of developing industries (Junior, 2006). Due to requirements for the rational use of natural resources by environment enforcing departments, textile industries have tried to modernize their equipments and provide ecologically correct products and processes with the least use of natural resources (Santos, 2002).

Water derived from textile industries is a heavy liability in the budget since it is not merely a step within the low-cost dyeing process. Industries have been investing heavily in alternatives for the direct or indirect reuse of waste baths and for minimum treatment possible to make viable reuse without jeopardizing the quality of the final product or excessively increase the costs (Twardokus, 2004).

Current research analyzes alternatives for water reuse in the dyeing process of fibers with 100% polyester and polyester with elastane dyed with dispersed dyes and polyamides with acid dyes. Current analysis focuses on the effects of water reuse in the dyeing process of tissues and the evaluation of their quality, decrease of environmental impact and production costs.

2. MATERIALS AND METHODS

2.1 Materials

Cloth for tests consisted of yarns 75/72, weighing 0.140 g/m^2 for 100% polyester tissue (PES); 75/72 98% polyester and 2% elastane from elastane 40 weighing 0.240 g/m^2 for polyester with elastane tissue (PES/PUE); and yarns 78F68 x 2 80% and 70F68 x 1 20% weighing 0.150 g/m^2 for the 100% polyamide tissue (PA).

Dyes were divided into dispersed and acid, the former for PES 100% and PES/PUE and the latter for PA 100%. PES tissue samples were yellow, red, navy blue and black. The same hues were used in the case of PES/PUE cloth, coupled to black, specific for PES/PUE cloth. Yellow, dark red, navy blue and black were employed for PA cloth. Table 1 shows the dyes used in current analysis.

Table 1 – Dyes for the dyeing process.

Dye	**Symbol**
Yellow	PES (Polyester)
Red	PES (Polyester)
Navy blue	PES (Polyester)
Black	PES (Polyester)
Black	PES/PUE (Polyester with elastane)
Yellow	PA (Polyamide)
Dark red	PA (Polyamide)
Navy blue	PA (Polyamide)
Black	PA (Polyamide)

2.2 Dyeing of samples

Sample dyeing was prepared according to dyeing concentrations in dyeing baths and difference in water reuse proportion of. Dyeing formulation standards were undertaken for the dyeing plan. A specific formulation was performed for each type of cloth so that the characteristics of each could be complied with. Tables 2, 3 and 4 demonstrate formulations respectively for clothes 100% PES, PES/PUE and 100% PA

Table 2 – Hues used in dyeing

	Yellow PES	Red PES	Navy blue PES	Black PES
Average	0.4%	0.4%	0.4%	
Dark	0.5%	0.5%	1%	
Black	0.5%	0.5%		3%

Table 3 – Formula for PES/PUE cloths.

	Yellow PES	Red PES	Navy Blue PES	Black PES/PUE
Average	0.4%	0.4%	0.4%	
Dark	0.5%	0.5%	1%	
Black	0.5%	0.5%		3%

Table 4 – Formula for PES/PUE cloths.

	Yellow PA	Red PA	Navy Blue PA	Black PA
Average	0.4%	0.4%	0.4%	
Dark	0.5%	0.5%	1%	
Black	0.5%	0.5%		2%

Dye planning of 100% PES, PES/PUE and 100% PA cloth was done according to the proportion of water reuse. Nine samples were dyed, with sample 1 as control dyed with 100% clean water. Table 5 shows respectively dyeing plan of samples 100% PES, 100% PES/PUE and 100% PA. Dyes were diluted at 1:50 for Black and 1:100 for the other hues. Auxiliary products were diluted in water at 1:20. Bath proportion in the dyeing process of the samples was 1:15, or rather, 5 g of the substrate for 75 mL of bath.Samples of each type of cloth used in the assay were cut to weigh approximately 5 g (with a possible 5% error) and identified according to the proportion of reuse water. Samples were collected from the dyeing process effluents directly at the machine exit and then forwarded to the effluent treatment process.

The separation of the laboratory dyeing vessels was undertaken to prepare the dyeing baths. Dyes and other necessary auxiliary products were added according to each formulation and type of cloth. Water was added up to 75 mL. Vessels were sealed and forwarded to the dyeing equipment Mathis, at 135°C for the 100% PES cloth; at 130°C for PES/PUE cloth; at

105°C for 100% PA cloth. After 45 minutes in the dyeing equipment process, recipients were cooled at 40°C; samples were then washed.

Table 5 – Dyeing plan of samples 100% PES, 100% PES/PUE, 100% PA.

Samples	Tone	Effluent
Sample 1	Average / Dark / Black	100% clean + products (white)
Sample 2	Average / Dark / Black	25% reuse 75% clean + products
Sample 3	Average / Dark / Black	25% reuse 75% clean + buffer
Sample 4	Average / Dark / Black	50% reuse 50% clean + products
Sample 5	Average / Dark / Black	50% reuse 50% clean + buffer
Sample 6	Average / Dark / Black	75% reuse 25% clean + products
Sample 7	Average / Dark / Black	75% reuse 25% clean + buffer
Sample 8	Average / Dark / Black	100% reuse + products
Sample 9	Average / Dark / Black	100% reuse + buffer

Further, pH was taken according to Standard Methods for Examination of Water and Waste Water, by glass electrode with a pH-meter, at a precision +/- 0.1 unit pH (Standard Methods for Examination of Water and Wastewater, 2005).

2.3 Textile Substrate

Tone was analyzed for the textile substrate with regard to the standard of the dyed color, parallel with test, by tolerance limits equal to those used for exportation standards. Dyed substrate was folded four times and then two consecutive measures were taken by spectrophotometer. Results were given as a function of tone variation (ΔE) and color intensity. Substrates were compared to samples dyed in 100% clean water. Solidity test in sample washing was evaluated following NBR ISO 105-C06.

3. RESULTS AND DISCUSSION

Color is a subjective perception on the brain as a consequence of energy beamed to the eyes (SALEM, 2000). According to Crisment (1998), colorimetry is a technique for measuring color. Color measured in a certain object is due to a luminous source, characteristics of material, object and three chromatic responses of the observer. These precise and quantified data characterize perfectly color since experience shows that three numerical rates are sufficient to identify the color spectrum of the object´s surface and the light source. Such simplification is the fundamental axis of three-chromatic vision. Figures 1, 2 and 3 show the behavior of tone variation for 100% PES, 100% PES/PUE and 100% PA cloths.

Figure 1 – Tone variation (ΔE) for 100% PES cloth.

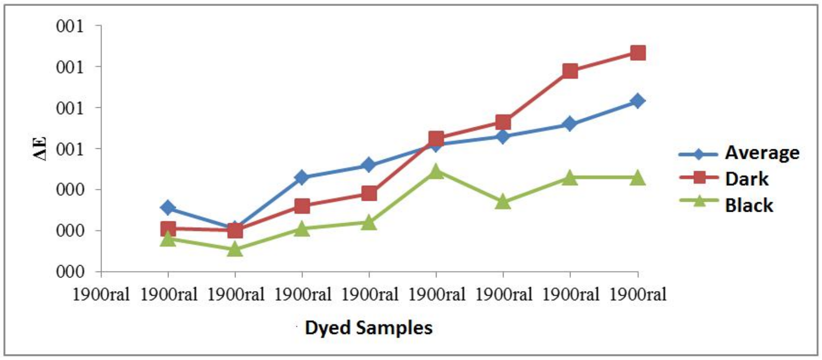


Figure 2 – Tone variation (ΔE) for 100% PES/PUE cloth

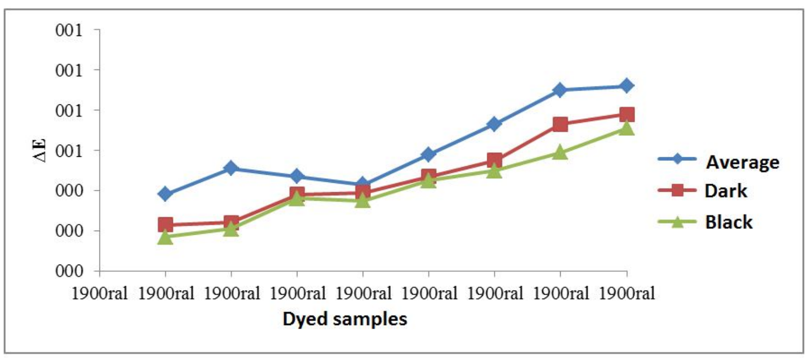
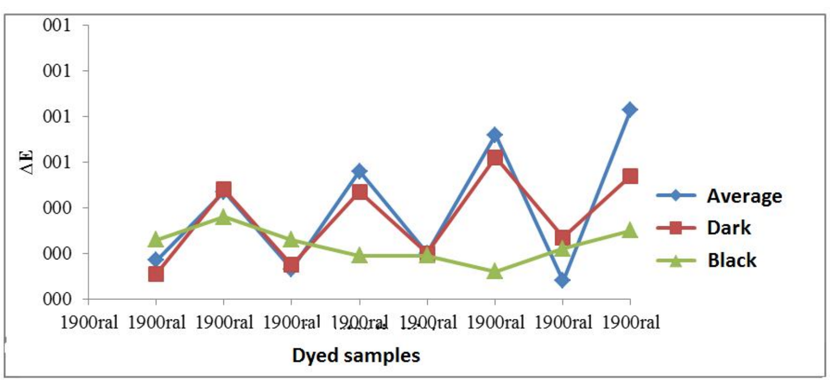


Figure 3 – Tone variation (ΔE) for 100% PA cloth.



Dyeing of 100% PA cloth samples provides more satisfactory results than that of other textile fibers. Since all dyed samples plus auxiliary products did not exceed 0.3 ΔE, the reuse of 100% of water and the addition of auxiliary products comply with specifications of main clients. Similar to dyed samples with the addition of auxiliary products, samples dyed only with the addition of acid donator also comply with the needs of a demanding market. The exception is the reuse of 100% of water in the average tone, with a $\Delta E = 0.8$, satisfying tolerance of market B.

Within the context of evaluating the solidity of cloth color, changes in the original color (fading) and/or staining or color transference in the standard test cloth are measured by the visual comparison of assays tested with AATCC grey scale for color change and staining and chromatic transference scale. Sample 1 was the reference for all dyed samples since it was dyed with 100% clean water. All samples dyed in average and dark tones did not reveal any difference between the sample dyed with 100% clean water and 100% reused water. A small variation occurred in samples dyed in black, with a minimum score of 3, or rather, a classification acceptable within specifications. Result was due to the excess of residual dye in the reused water, making impossible the fixing of the hue in the dyed cloth. Hue migration remained stable for the different percentages of reused water. Results were satisfactory since they evidenced that water reuse did not affect the cloth´s quality parameters.

Further, pH of bath may influence the behavior of the hue in various ways. A hue may be converted into a more soluble form by the ionization of the hydroxyl group, with a different behavior during dyeing. In extreme conditions, certain hues may hydrolyze, change their behavior and even their tonality. Samples dyed with average and dark tones in PES, PES/PUE, PA cloths have a decrease in pH from 4.0 to 3.5, according to increase in the proportion of reused water. The quantity of hue added was not enough for constant pH. Samples dyed in black tones had a constant pH regardless of the proportion of water reuse used in dyeing.

4. CONCLUSION

The textile process has several water flows which generate liquid effluents and many options of textile fibers for processing. Current assay restricted certain variables, such as type of cloth to be processed and type of hue for cloth dyeing. The above are parameters that determine the approval of final color (ΔE) and solidity in washing.

The data above show that, regardless of the proportion of reused water, other parameters under analysis, such as ΔE, pH and solidity to washing, evidenced linear and satisfactory results. Absorbance analysis was an exception since it showed a behavior with irregular variation even though within what was expected.

Results show that the direct reuse of water in the cloth dyeing process is feasible when the quality of the dyed cloth is taken into consideration. Within the context of the industry and its reuse of the process´s effluent flows, an estimated 75% saving of auxiliary dyeing products may be obtained coupled to an approximate 40% decrease of effluents which would pass in the liquid treatment process. The above would help in the direct treatment of water sourcing and in the effluent´s final treatment. It directly contributes towards the environmental process in the industry and towards a sustainability model.

5. REFERENCES

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