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Colored Nanoparticles for Ecological Dyeing of Cellulosic Fibres

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Abstract: Dyeing cellulosic fibres with reactive dyes wastes great quantities of salt and water. The objective of this work is to dye cellulosic fibers using colored nanoparticles (CNPs) as an alternative to dyeing with reactive dyes, without salt and without washing off at the end of dyeing.
Samples of cotton were dyed by exhaustion with CNPs at medium to dark colours. Build-up of colour compared to samples from previous work is given and shows a big improvement. Washfastness results are given. Washing-off after dyeing was not necessary for the red and yellow colours. The blue colour needs some washing off since the fastness is lower than for the other colours even though soaping is not necessary, saving energy and time relative to dyeing with reactive dyes.

Introduction

The textile industry has been considered an activity of high impact on the environment mainly due to the effluent having high concentrations of organic compounds and visible coloration. Wet processes of the textile industry (pre-treatment, dyeing and finishing) consume wide amounts of water and energy [1].

The costs of using great quantities of water or treating waste in industrial processes like conventional dyeing of textiles is a serious concern for textile manufacturers and finishers.

Of all dyed textile fibres, cotton occupies the number-one position, and more than 80% is dyed with reactive dyes. Unfortunately, this class of dyes is also one of the most unfavourable one from the ecological point of view, as the effluents produced are relatively heavily colored, contain high concentrations of salt and exhibit high BOD/COD values. Dyeing 1 kg of cotton with reactive dyes requires an average of 100–150 L water and 0.6 kg NaCl. The composition of the dyebath contains solid particles (cotton fibres), dyeing auxiliaries (organic compounds), hydrolyzed reactive dyes, substantial quantities of alkalis (sodium carbonate and soda ash) and very high concentration of sodium chloride or sodium sulphate [2].

Using appropriate synthesis conditions and by careful selection of dyes, a large number of dye molecules can be incorporated inside a single silica particle. Since it is applied in the liquid form, allergy and potential cancer risk phenomena for the workers using the dyes can be minimized. In previous work colored silica nanoparticles were applied to wool fibres with good results on the washfastness and the levelness. Preliminary studies were also done on silk and cotton with light colors [3].

These studies work have led to the present work of dyeing cotton fibres with colored nanoparticles in medium to dark colours.

Nanoparticles preparation and characterization

Silica nanoparticles containing dyes and other water soluble compounds have been obtained using different methods. In this work silica nanoparticles containing dye, were obtained from a typical sol-gel reverse emulsion (W/O) with an aqueous dye solution. The process was an adaptation of the Stober method.[4]. A dye was then immobilized onto the nanoparticles by a doping method [5,6].

Dyes were chosen amongst small molecular weight acid dyes so as to pack sufficient dye into the particles and with a NH2 group in their chromophore so that the reaction with the organosilane takes place. The particles were characterised previously by TEM and SEM, and their size had been measured in a previous work on their application to hair [7].

Dyeing with Colored Nanoparticles

Cotton fabric (100%) was dyed in a solution containing a dispersion of CNPs at a liquor to fabric ratio of 10:1. The cotton CNPs dyeing experiments were performed at 80ºC and at pH 8, and were carried out in a Linitest machine. For the control experiments, fabrics were dyed using the same conditions described above, except that instead of using CNPs, dyes at the same concentration, were used.

By measuring the K/S the equivalent concentration of CNPs was calculated. In previous work the colour uniformity and the fastness to washing and to staining of cotton samples dyed with CNPs, were at least as good as those obtained by reactive dyes at 0,15%.[3].

In this work different dyes were used to prepare the CNPs so as to obtain darker colors. For the red color it was possible to increase the K/S more than seven times, obtaining an equivalent dye concentration of 3%. Washfastness was done according to ISO105CO6-C1.

Table 1. Comparison of cotton fabrics dyed with different concentrations of red CNPs

Equivalent dye concentration	K/S	Wash fastness	
		Colour alteration	Staining on cotton
0.15% o.w.f.	0.75	4-5	5
1.5% o.w.f.	4.92	4	5
3%	6.27	4	4

As can be seen from table1, build up was possible up to 3% o.w.f.. Even at this high concentration the washfastness without any washing off was high.

CNP´s for the other colors in the thricromy, royal blue and golden yellow were also prepared. The K/S and fastness results are in table 2.

Table 2. Comparison of cotton fabrics dyed with different concentrations of blue and yellow CNPs

	K/S	Wash fastness	
		Colour alteration	Staining on cotton
CNP's blue 3%	4,69	3	3
CNP's yellow 3%	1,48	4	4

Ecological issues

The method of dyeing with CNPs has great environmental benefits compared to traditional processes. The dyeing of cotton does not require salt (in cotton) and washing off is a lot less and soaping not necessary, saving time and large quantities of water and energy. Washing off of the

CNPs is easier than washing off hydrolysed dye since the affinity is a lot lower for the CNPs. Judging from the washfastness results of table 1, only the blue colour probably needs a sequence of rinses at 60ºC but no soaping. The other colours only need one rinsing in cold water.
Another advantage is to obtain an effluent with more ecological parameters, since most of the colour is in the form of silica nanoparticles and can removed by precipitation.
Using this technology, the effluent resulting from dyeing with CNPs has no free dye. From the waste water, the colour seen is due to the presence of CNPs that were not absorbed by the fibres, which after an hour settle to the bottom of the tank, allowing the separation of the solid phase (CNPs), from the aqueous phase (water), as shown in Fig.1. After phase separation is possible to reuse the water and the CNPs in a new bath dyeing.

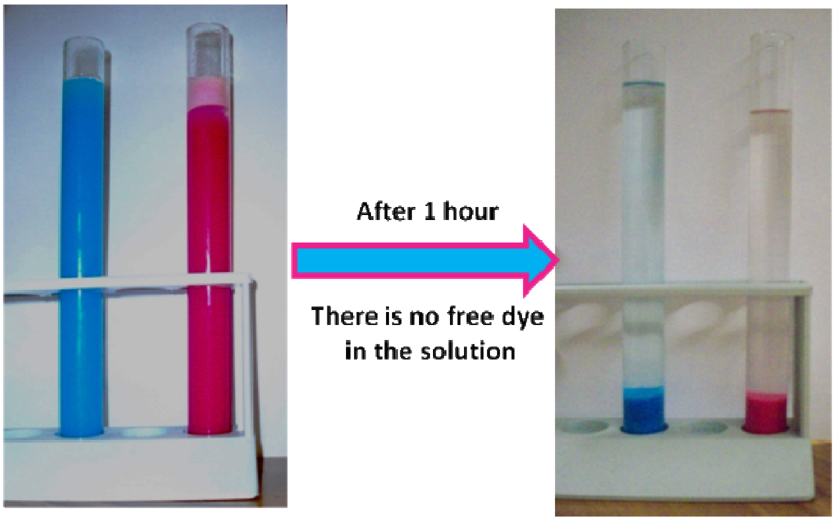

Fig. 1: Separation of the aqueous phase from the solid phase (CNPs).

Since no dye is left in the effluent and it is easy to separate de CNPs from the dyeing bath, the CNPs and the water can be recovered and reused.

Conclusions

Cotton fibres were successfully dyed with CNPs with no salt. Cotton fabrics showed good fastness to washing and to staining, and showed good colour uniformity. The process is a lot more ecological than traditional dyeing, using no salt and less water, and with the colored nanoparticles there is the possibility to recover and reuse water and CNPs from previous dyeing.
Next steps are the use of CNPs in industry, so as to validate the laboratory results.

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