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The kinetics of colour change in textiles and fibres treated with detergent solutions Part II — Spectrophotometric measurements

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ABSTRACT

The aim of this study was to assess colour variations that occur in several types of textiles and their constituent fibres, resulting from the long-term influence of various laundry detergents. A 14-day experiment was conducted using blue, red and grey/black cotton, wool, acrylic and polyester textiles. The spectrophotometric measurement of colour changes in fabric samples and test solutions, as well as the microspectrophotometric analysis of colour changes in single fibres were described. An evaluation of the observed colour changes from a forensic fibre analysis expert's point of view, as well as that of an average user/consumer of the textiles and laundry detergents is also provided.

1. Introduction

Laundry detergents are complex mixtures, involving a wide range of substances that inter-react in the washing solution. Beyond the basic, superficially active substances, modern laundry detergents contain a wide variety of additives and enhancing ingredients–such as bleaching agents and their chemical activators, enzymes, and colour-transfer inhibitors–which could influence the change in the colour of a textile [1].

Other factors that influence the durability of fibre and textile dyes include: the type of fibre, the chemical structure of the dye used, as well as a number of other factors associated with the chemistry of the finishing process that is applied to a given textile product [2].

The research presented involved assessing colour changes in selected clothing textiles and fibres that had been subjected to long-term, repeated treatment with a number of different laundry detergent solutions. The aim of the study was to evaluate the effects that the respective varieties of detergent solution have on specific types of dyed textiles.

The sensory analysis consisted of a visual evaluation of the colour changes in textile samples, and the kinetics of the colour changes in the fibres, which were tracked using fluorescence microscopy (UV excitation filter), have already been reported [3]. The subject of this part of the study are the results of the spectrophotometric measurement of the colour changes in fabric samples and test solutions, as well as the microspectrophotometric analysis of colour changes in single fibres.

2. Experimental

The following samples of single-coloured blue (B), dark grey (G) and red (R) fabrics and yarns, available on the consumer market (produced in Poland, China, Korea) were used in the experiments:

- three T-shirts, made of cotton (100% Co) knitted fabrics, produced in China and Poland under the "Reserved" brand name, coloured using direct dyes. These samples were labelled in the experiment as "CoB", "CoG" and "CoR";
- three wool fabric samples (100% Wo), produced by Bielska Welna (Poland), coloured using acid dyes and labelled in the experiment as "WoB", "WoG" and "WoR";
- three polyester fabric samples (100% PES), produced in Korea, coloured with dispersed dyes. These samples were labelled "PeB", "PeG" and "PeR".
- three hanks of acrylic yarn (100% Ac), produced by Anilux S.A. (Poland), coloured with basic dyes; the samples were labelled "AcB", "AcG" and "AcR".

All of the textile samples used in the experiment were new, never previously laundered, and suitable for home laundering, according to their manufacturers' specifications.

Experiments were conducted using powdered and liquid laundry detergents that were available on the Polish market, as well as in other European countries; these products were selected on the basis of the popularity and their compositional diversity [4–7]:

"Ariel" (Platinum Colour), produced by Procter & Gamble;
"E" (Automat Extra Active), by PZ Cussons Poland;
"Bryza" (Colour, Soapflake-strengthened), by Reckitt Benckiser;

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Table 1
The textile samples and detergents used in the experiment.

Textile samples			Detergents				
Source	Colour	Labelling	No. 1	No. 2	No. 3	No. 4	No. 5
Cotton knitted fabrics	Red	CoR	✓	✓	✓	✓	✓
	Blue	CoB	✓	✓	✓	✓	✓
	Grey	CoG	✓	✓	✓	✓	✓
Wool fabrics	Red	WoR			✓		✓
	Blue	WoB			✓		✓
	Grey	WoG			✓		✓
Polyester fabrics	Red	PeR	✓	✓	✓	✓	✓
	Blue	PeB	✓	✓	✓	✓	✓
	Grey	PeG	✓	✓	✓	✓	✓
Acrylic yarns	Red	AcR	✓	✓	✓	✓	✓
	Blue	AcB	✓	✓	✓	✓	✓
	Grey	AcG	✓	✓	✓	✓	✓

✓-used in the experiment.

"Dosia" (Active Oxygen Power Colour), also a Reckitt Benckiser product;

"Perwoll" (Colour Magic + Colour Fix), by Henkel.

These experiments were conducted over the course of 14 days. The proportions of detergent in the solutions (prepared with regular tap water or distilled water) were in-kept with the manufacturers' specifications. The treatments applied to the experimental textile samples are specified in Table 1. The textile samples submerged in detergent solutions were stored at 40 °C in a thermostatic cabinet. Each detergent solution was changed and replaced with a fresh one on a daily basis. The details concerning the course of the experiment were described previously [3].

3. Measurement of colour variations in the fabric samples

The colour measurement data from the initial and experimental fabric samples was provided in remission values from the entire visible spectrum. The standard chromatic values of a colour X, Y and Z were used for calculating other colorimetric indices and definitive arithmetic descriptions of colour variations, such as ΔE_{CIELab}.

Spectroscopic measurements (remission spectra) were recorded on Macbeth 2020+ diffuse spectrophotometer; the illuminant D65 and $d/8°$ geometry were used. The sample was placed on the black background (remission factor $R<4\%$) and was scanned in the wavelength region of 400–700 nm with an interval of 20 nm.

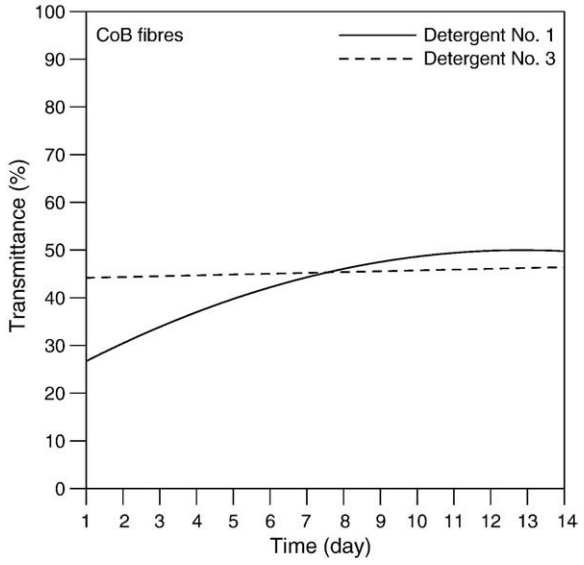

Fig. 1. Changes in transmittance values for minima in spectra of blue cotton fibres from CoB fabric samples treated with solutions of Detergent No.1 and 3 in distilled water.

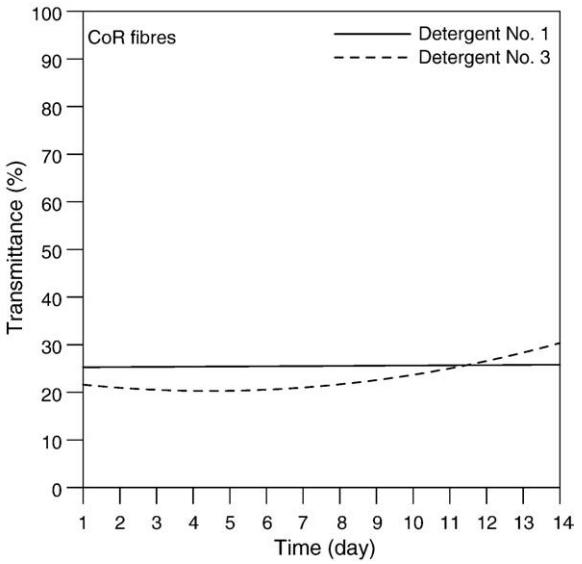

Fig. 2. Changes in transmittance values for minima in spectra of red cotton fibres from CoR fabric samples treated with solutions of Detergent No.1 and 3 in distilled water.

In the case of CoR fabric samples that were treated with detergent No. 1, significant colour differences between the initial samples and those taken from subsequent days of the experiment were not observed, in contrast to the results obtained when testing fibres from these samples using fluorescence microscopy (UV excitation filter) [3]. This was borne out, among other things, by the low ΔE_{CIELab} values, which fell within the range of 0.65–2.71.

A change of colour in the textile products was observed for WoB samples treated under the influence of the solutions of detergent No. 3. Colour changes for these samples were calculated and high ΔE_{CIELab} values, which already amount to 5.70 on the 4th day of the experiment, and reached 23.64 by the time of its conclusion were observed. It can be determined that the colour of the WoB samples proved to be unresistant to the composition of detergent No. 3.

4. An assessment of colour variations in single fibres

The next phase of the testing involved taking microspectrophotometric (MSP) measurements of colour changes of both treated and

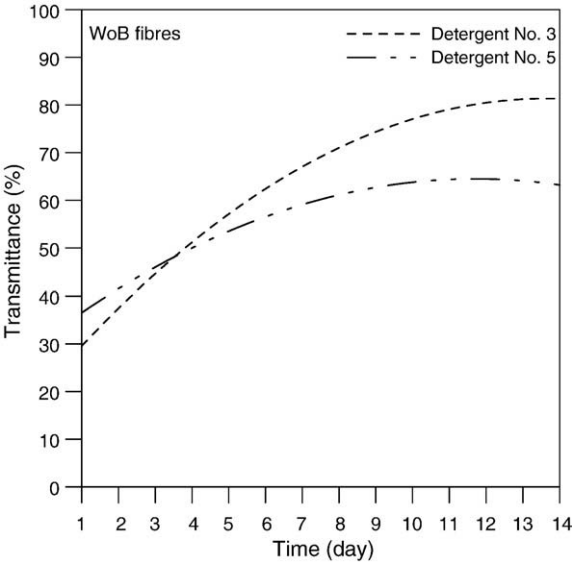

Fig. 3. Changes in transmittance values for minima in spectra of blue wool fibres from WoB fabric samples treated with solutions of Detergent No. 3 and 5 in distilled water.