*Tanja Pušić, Katia Grgić, Ivo Soljačić*
University of Zagreb Faculty of Textile Technology, Zagreb, Croatia

# PERACETIC ACID EFFECTIVENESS IN LAUNDERING OF COTTON FABRICS

*Abstract*

*Selection of proper chemicals in laundering should meet numerous requirements, e.g. efficient removal of various soils at low temperature and short time with minimal water consumption. Environmental considerations have a considerable influence in contemporary detergent formulations. Systematic investigations of detergent components and their impact on the environment have shown that some of them, in despite of their beneficial activity in laundering, are characterised by poor biodegradation, and present a considerable load on waste waters, either directly or through their interactions with other waste products in water. The aim of the study was to analyse laundering performance of detergent containing environmentally favourable peracetic acid (PAA) in variation of pH and finishing.*

*Keywords: cotton, laundering, detergent, peracetic acid*

## 1. INTRODUCTION

Detergency is dependent on specific interactions among substrate, soil and detergent components. The impact of chemistry on stain removal ability depends upon the composition and concentration of laundering agents [1]. Surfactants are key elements, as they are, due to their hydrophobic-hydrophilic nature, essential for proper soil particle dispersion (soot) and emulsifying liquid soils (oils and fats that liquefy at the temperatures above 50°C [2]. Synergy of surfactants and other components significantly reduce redeposition in laundering. It was necessary to consider mutual interactions of the laundering components, but also the interactions among various classes of soil. The most difficult soil to remove from fabrics are pigments, such as carbon black (soot), inorganic oxides, carbonates and silicates Other problematic soils include fats, waxes, higher hydrocarbons, denaturated proteins, and certain natural dyes. Problematic stains are mostly present on fibres in the form of mixed soils, e.g. stains from food, kitchen or cooking [3]. The absorption and retention of soils by textile fibres occur by a variety of mechanisms, each contributing to the resultant greying, and yellowing and whiteness deterioration of a fabric. The presence of bleaches is of key importance due to decolourization of stains from textiles to be laundered. Bleach is not associated only with better performance but also with drawbacks such as fibre damage after frequent laundering [4]. Hydrogen peroxide is quite an effective bleaching agent at the temperatures above 70°C. Nowadays, sustainable requirements have resulted in continued efforts toward low temperature (LT) processes. The role of bleach is to decrease the risk of oxidative damages to cellulose fibres and eliminate the bacteria resistant to hydrogen peroxide, resulting in better hygiene of washing, even in LT processes [4]. Due to disinfection effectiveness and environmental benefits, peracetic acid (PAA) is an alternation to existing bleach component. Its products of decomposition are biologically degradable [5] It is mostly used in the main wash in the temperature range from 60 to 70°C. Above the 70°C, the PAA decomposes too rapidly. As a peroxy compound have an optimal bleaching effect in an alkali medium. The pH range for peracetic acid application is in the range of pH 8.0 – 10.0, depending on the requirements and other process parameters. If active oxygen from PAA in the last rinse is not neutralized, there is a potential risk that oxygen stored in the textiles becomes more reactive during drying or ironing, when it can cause a further chemical damage of the processed textiles. The executed research deals with laundering performance of ecologically applicable agents, including a peracetic acid (PAA), evaluated through primary and secondary effects before and after ironing (i).

## 2. EXPERIMENTAL

### 2.1. Material

The evaluation of a primary laundering effect was performed on EMPA test fabric No. 103 (Tab. 1).

**Table 1.** Composition of EMPA cotton fabric

| No. | Stain | Effect/Indication |
|---|---|---|
| 221 | Bleached cotton fabric | Redeposition |
| 101 | Carbon black/olive oil | General |
| 111 | Blood | Removal of the protein stain |
| 112 | Cocoa | |
| 116 | Blood/milk/ink | |
| 115 | Immedial black | Bleaching effect |
| 222 | Raw cotton fabric | |
| 114 | Red wine | |

Secondary effects of laundering conditions (Tab. 2) are evaluated on a reference cotton fabric, SCC (DIN 53919-1, 1980).

Primary effect is evaluated by stain removal (DY) through spectral characteristics of EMPA 103 after a single laundering cycle. Secondary effects were evaluated by RAL-GZ 992/1 quality criteria, which included decrease in breaking strength, chemical wear, incineration residue and whiteness degree [6]. Surface characterization of cotton fabrics was performed by the streaming potential method in Electrokinetic Analyzer and Scanning Electron Microscopy (MIRA\FE-SEM) [7].

**Table 2.** Laundering conditions

| Process | Agent | Dosage g/g | T °C | t min |
|---|---|---|---|---|
| Prewash | NaOH (48%)<br>NS | 2<br>2 | 40 | 10 |
| Wash | NaOH (48%)<br>NS<br>PAA<br>FWA | 2<br>2<br>2<br>0.5 | 60 | 15 |
| 2 cycles rinsing | | | | 2<br>2 |
| Neutralization | $CH_3COOH$ | 0.2 | | 4 |
| Rinsing | | | | 2 |
| Extraction | | | | 5 |

NS-nonionic surfactant; FWA-fluorescent whitening agent

## 3. RESULTS

Stain removal from reference EMPA test fabric laundered in presented conditions, where pH of main wash varied, pH 8.4 (PAA*) and pH 9.8 (PAA) is presented in Tab 3.

**Table 3.** Stain removal

| Textile material stained with | | ΔY | |
|---|---|---|---|
| | | *PAA* | *PAA** |
| **221** | – | 9.56 | 8.47 |
| **101** | Soot/olive oil | 8.77 | 9.39 |
| **111** | Blood | 64.30 | 50.31 |
| **112** | Cocoa | 4.46 | 7.60 |
| **116** | Blood/milk/ink | 15.06 | 9.96 |
| **115** | Sulphur soot | 6.74 | 5.10 |
| 122 | Raw fabric | 6.43 | 6.59 |
| 114 | Red wine | 10.30 | 18.01 |
| TOTAL ΔY | | 125.61 | 115.42 |

Laundering bath containing PAA* (pH 8.4) resulted with better bleaching effect analysed through removal of red wine (114). It proves better discoloration of stains and higher potential of PAA at 8.4 in comparison to pH 9.8. PAA is able to set protein stains, so a pre-wash was performed due to treatment of blood stained textiles before the use of PAA in a main wash. Protein stains (116 & 111) were better removed in a bath of pH 9.8. Protein stains require high alkali conditions.

Secondary laundering effect was analysed after 10 cycles by evaluation of *ash content, decrease in breaking strength, chemical wear, whiteness quality, zeta potential and SEM images*.

**Table 4.** Ash content (A) of cotton fabrics

| Laundering bath/cycles | A (%) | | | | |
|---|---|---|---|---|---|
| | 0 | 3 | 10 | 3i | 10i |
| PAA | 0.35 | 0.26 | 0.18 | 0.28 | 0.18 |
| PAA* | | 0.12 | 0.06 | 0.15 | 0.10 |

The results of ash content showed an absence of inorganic incrustations due to laundering in a soft water.

**Table 5.** Breaking strength (Fp) and decrease in breaking strength (ΔF) of cotton fabrics without and with ironing (i)

| cycles | PAA | | PAA* | |
|---|---|---|---|---|
| | Fp [N] | ΔF [%] | Fp [N] | ΔF [%] |
| 0 | 913 | – | 913 | – |
| 10 | 851 | 6.79 | 717 | 21.46 |
| 10i | 845 | 7.44 | 627 | 31.32 |

Decrease in breaking strength (ΔF) of the laundered cotton fabrics compared to the initial sample one show that laundering with at pH 8.4 (PAA*) caused higher reduction of mechanical properties than PAA at pH 9.8, Tab 5. Significant reduction of breaking force of laundered cotton fabrics (21.46%) and further increase after ironing (31.3%) could be attributed to the unbalanced conditions.

**Table 6.** Chemical wear (s) of cotton fabrics

| Cycles/processing | PAA | PAA* |
|---|---|---|
| 10 | 0.60 | 0.53 |
| 10i | 0.74 | 0.46 |

Chemical wear of the cotton cellulose after 10 cycles with PAA and PAA*, without and with ironing (i) showed that high concentration of per-hydroxyl ions ($HO_2^-$) in a short span of time as well as their liberation and activity in the laundering bath caused damages to the cotton cellulose. PAA (pH 9.8) caused a stronger degradation of cotton cellulose than PAA* (pH 8.4), that was continued in ironing samples. Whiteness quality of cotton fabric is monitored through spectral parameters, Tab 7.

**Table 7.** Whiteness degree ($W_{CIE}$) of cotton fabrics

| | $W_{CIE}$ | |
|---|---|---|
| cycles | PAA | PAA* |
| 0 | 67.7 | 67.7 |
| 1 | 106.28 | 91.9 |
| 3 | 115.02 | 96.6 |
| 1i | 104.99 | 91.8 |
| 3i | 114.44 | 96.3 |

The whiteness degree of SCC before laundering is 67.7 that indicates an absence of fluorescent whitening agent (FWA). Laundering in a bath that contained FWA through 3 cycles stimulated a whiteness enhancement. Higher alkalinity (PAA) had better effect on a whiteness quality of SCC than PAA*.

Fibres surface charge is an important parameter in the wet processing of cotton [7,8]. Surface characterization of cotton fabrics by zeta potential can be highly valuable for evaluation of secondary effects, Fig 1.

Zeta potential curves of cotton fabrics showed that alkali conditions of laundering bath caused changes of cotton fibre surface. Impact of PAA (pH 9.8) is higher than PAA* (pH 8.4) due to higher swelling capacity of cellulose. There is no significant impact of ironing on the surface of cotton cellulose.

SEM micrograph of the fabric before laundering show an integrated structure and recognizable appearance of the cotton fibres. Laundering caused changes in cotton, due to its high swelling in the alkali media, the impact of bleaches, mechanical agitation and ironing. Generally, SEM images of tested fabrics show a signs of damage in the case of cotton fabrics after 10 cycles through disintegrated surface and fibrillation, Fig 2. The surface changes are more pronounced on samples laundered in a bath with PAA*.

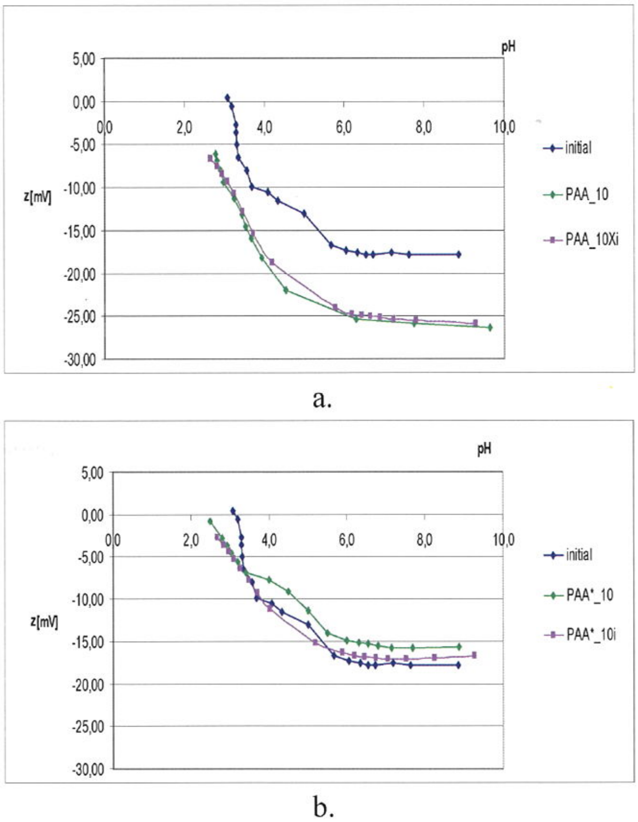


**Figure 1.** Zeta potential of cotton fabrics in dependence of pH of 1 mmole/l KCl

## 4. CONCLUSIONS

Primary effect evaluated through total soil removal in laundering bath with the addition of PAA (pH 9.8) and PAA* (pH 8.4) varied in removal of protein and coloured stains. Blood was better removed at pH 9.8, while red wine was removed efficiently at pH 8.4. Secondary effects in laundering bath with PAA and PAA* proved that synergy of chemical and mechanical parameters impact on degradation of cotton fabrics and reduction of their mechanical properties. In general, PAA caused more pronounced changes of mechanical properties than chemical ones. Surface characterization of cotton fabrics by electrokinetic behaviour and SEM images proved to be convenient for evaluation of secondary effects. Finally, the overall results of primary and secondary effects showed that the application of peracetic acid in laundering is a sensitive procedure, so it necessary to optimize pH of laundering bath.


## *ACKNOWLEDGEMENTS*

This research was funded through the project FP7-SME-2007-2, SMILES 217809, Sustainable Measures for Industrial Laundry Expansion Strategies: SMART Laundry-2015, funded by the European Commission.


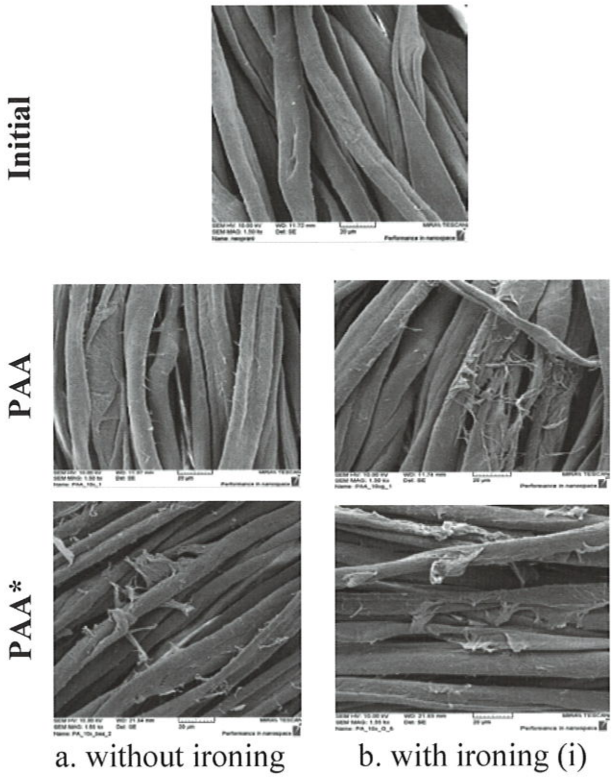


**Figure 2.** SEM images of cotton fabrics after 10 laundering cycles

## REFERENCES


[1] Zoller, U., *Handbook of Detergents*, Marcel Dekker, New York, (2004)

[2] Soljačić, I., T. Pušić, *Textile care* (in Croatian), University of Zagreb, Zagreb (2005)

[3] Smulders, E., *Laundry Detergents*, Wiley-VCH, Weinheim, (2002)

[4] Reinhardt, G. and Ulshöfer, H., Testing Robustness and Compatibility of Colour Damaging Washing Tests, *Tenside Surfactants Detergents,* **43**, 12-19 (2006)

[5] Forte-Tavčer, P. Effects of Cellulase Enzyme Treatment on the Properties of Cotton Terry Fabrics, *Fibres & Textiles in Eastern Europe,* **21**, 100-106, (2013)

[6] Fijan, S., Šostar-Turk, S., Neral, B., Pušič, T., The Influence of Industrial Laundering of Hospital Textiles on the Properties of Cotton Fabrics, *Textile Research Journal*, 77, 247-255, (2007)

[7] Grancarić, A.M., Tarbuk, A. and Pušić, T. Electrokinetic properties of textile fabrics, *Coloration Technology*, **121**, 221-227, (2005)

[8] Jacobasch H.J. and Grosse I., Anwendung der Zeta-Potential-Messung in der Textilforschung und praxis, *Textiltechnik,* **37**, 266-268; 316-319, (1987)


More information on the project public website:
http://cordis.europa.eu/project/rcn/97981_en.html

Funded by the European Union

SEVENTH FRAMEWORK PROGRAMME