THE EFFECTS OF WASHING CONDITIONS ON SOIL REMOVAL IN DOMESTIC LAUNDERING PROCESSES

Aysun Cireli, Merih Sarıışık, Bengi Kutlu, Volkan Yaman*

Dokuz Eylül University, Department of Textile Engineering, Izmir- Turkey
*Günkol Güneş Enerjisi ve Klima Sistemleri A.Ş. (TEBA), Izmir-Turkey
E-mail: merih.sariisik@deu.edu.tr

Abstract

In the domestic laundering process, relatively high wash temperatures and long wash times have traditionally been used for optimum soil removal. The use of lower wash temperatures could result in a substantial reduction in the amount of energy used in laundering. The purpose of this study was to determine soil removal from cotton, polyester, polyester/cotton, wool and wool/polyester fabrics at a range of wash temperatures, wash times, pre-wash times and liquor ratios. The samples were soiled with sebum, coke, instant coffee, sour cherry juice and meat sauce. Soil removal was determined by the differences between remission values of fabrics before and after washing. Optimum temperature and times for soil removal was estimated for all soils and fabrics.

Key words:

soil removal, washing machine programs, laundering,

Introduction

Maintaining textile products consumes significant amounts of energy, and is extremely important to the satisfactory performance of these products. The laundering process uses approximately nine percent of the total household consumption of energy, and much of this energy is used in heating water. Traditionally it has been considered that hot wash temperatures were required for satisfactory soil removal from cotton fabrics, while lower temperatures would give adequate soil removal from fabrics of synthetic fibre. The use of lower wash temperatures for all fabrics could result in a substantial reduction in the amount of energy used in laundering [1].
Numerous variables affect the rate of soil removal and the cleanliness of the washed garment:

- washing equipment,
- time (length of the wash cycle and the pre-soak cycle, if included),
- agitation,
- temperature,
- detergent composition (and the structure of the surfactants),
- detergent concentration,
- bleach, if added separately,
- water hardness,
- load size and cloth-liquor ratio,
- rinse conditions (time, temperature, volume, agitation, and so on),
- drying conditions [2].

Table 1 shows the washing conditions of washing machines in Japan, the United States and Western Europe [3].
Washing is usually done within one of three temperature ranges: 90-100, 40-60˚C and at ambient temperature. The ASTM method recommends washing at 21, 37 and 54˚C. The maximum wash temperature depends on the type of washing machine used. Front loading washers used in Europe are equipped with heaters for raising the water temperature to 95˚C. In the United States, top loading washers are by far more popular, and wash temperatures are in the 40-60˚C range, usually at 55˚C, or washing is done at ambient temperature. Wash temperatures are decreasing, especially in Europe, mainly because of the increased cost of heating.

Table 1. Washing conditions in different continents [3]

Washing conditions	United States/Canada	Japan	Western Europe
Washing machine	agitator type	impeller type	drum type
Heating coils	no	no	yes
Fabric load, kg	2-3	1-1.5	3-4
Amount of wash liquor, L	extra small: ca.35 medium: ca. 50 large: ca. 65 extra large: ca. 80	low: 30 high: 45	low: 18-20 high: 25
Total water consumption, L (regular heavy cycle)	140	150	120
Wash liquor ratio	1:15- 1:30	1:20-1:30	1:5-1:25
Washing time, min	10-15	5-15	60-70 (90C) 20-30 (30C)
Washing, rinsing and spinning time, min	20-35	15-35	100-120 (90C) 40-50 (30C)
Washing temperature,ºC	hot: 50 (122F) warm: 27-43 (80-110F) cold: 10-27 (50-80F)	10-40	90 60 40 30
Water hardness, ppm $CaCO_3$	relatively low, 100	very low, 50	relatively high, 250
Automatic detergent addition	mostly no	mostly no	dispenser
Recommended detergent dose, g/L g/kg fabric	1.5 35-50	1.3 30-40	8-10 60-80
Peroxide bleach	+	(+)**	+
Chlorine bleach	+	(+)	(+)
Drying process by automatic dryer	+	(+)	(+)

* In the United States and Japan without bleaching components.
** Parentheses indicate that this element is less important.

The length of the wash cycle depends on the construction of the washing machine and the cycle selected in accord with the type of fabrics washed. The wash cycles of washers built in the United States are usually 8 to 15 min. Standard test procedures recommend washing for 10 to 12 min [2].
There are numerous publications, including several up-to-date textbooks, which deal comprehensively with aspects of surfactant science relating to the theory and technology of detergency [4-6].
The physical and chemical effects of domestic laundering process have been investigated by several researchers [7].
The purpose of this study was to determine soil removal from cotton, polyester, polyester/cotton, wool and wool/polyester fabrics at a range of wash temperatures, wash times, pre-wash times and liquor ratios. The samples were soiled with sebum, coke, instant coffee, sour cherry juice and meat sauce. Soil removal was determined by the differences between the remission values of fabrics before and after washing. Optimum temperature and times for soil removal was estimated for all soils and fabrics.

EXPERIMENTAL

Materials

For this study, five different types of white fabrics, which were pre-treated without optical brightener, were used. They are described in Table 2.
When choosing, soils were considered to be those that a person was likely to encounter during a normal day. The soils chosen were coke, sour cherry juice, instant coffee, sebum and meat sauce. Fabrics were padded with instant coffee, coke and sour cherry juice at room temperature. For padding, sour cherry juice and coke were opened and then used immediately. 0.01 g/l coffee solution

was prepared and 69 g/l sugars was added to the solution. The padding temperature of the solution was 70ºC. Pick-up ratio was 90%. Fabrics were dried flat.
Cotton, cotton/polyester blend, polyester and wool fabrics soiled with meat sauce and sebum were obtained from WFK Testgewebe GmbH. No wool/polyester blend fabric was soiled with these soils, and so the wool/polyester blend fabric with these soils was not used.
A good quality detergent, which is commercially available, was used in the proportions of 5 g/l for cotton, polyester and cotton/polyester fabrics and 3 g/l for wool and wool/polyester blend fabrics. The amount used for pre-wash cycles was 2.5 g/l. The detergent was composed of the following agents:

- cationic action agent, nonionic active agent, policarboxylate, and zeolit: below 5%;
- anionic active agent, oxygent based bleaching agent: 5-15%;
- phosphate: 15-30%.

Table 2. Description of fabrics

Fabric	Weight (g/m^2)	Yarn Setts (cm^{-1})		Yarn Counts (Nm)	
		Weft	Warp	Weft	Warp
100% Cotton (Co)	138	20	24	32	32
65% Cotton / 35% Polyester	208	17	41	14	60
100% Polyester (PES)	144	21	21	46	46
45% Wool / 55% Polyester	236	22	38	56/2	56/2
100% Wool	271	35	45	60/2	60/2

Methods

The study was designed as a factorial experiment with four factors; main wash temperatures (five), wash liquor ratios (two), main wash times (four) and pre-wash times (three). Two samples were prepared for each possible combination of factors. The plan of the experiments is given in Table 3.

Table 3. Plan of Experiments

	Temperature (˚C)						
	30		***40***		***50***	***60***	***80***
Fabric	Co	Wo	Co	Wo	Co	Co	Co
	Co / PES	Wo / PES	Co / PES	Wo / PES	Co / PES	Co / PES	Co / PES
	PES		PES		PES	PES	PES
Reversing Rhythm	12s rotation / 4s pause	4s rotation / 12s pause	12s rotation / 4s pause	4s rotation / 12s pause	12s rotation / 4s pause	12s rotation / 4s pause	12s rotation / 4s pause
Liquor Ratio	1:3	1:10	1:3	1:10	1:3	1:3	1:3
	1:5		1:5		1:5	1:5	1:5
Main Wash Times (min)	10	10	10	10	10	10	10
	15	15	15	15	15	15	15
	20	20	20	20	20	20	20
	25	25	25	25	25	25	25
Pre-wash Times (min)	0		0		0	0	0
	5		5		5	5	5
	10		10		10	10	10

An automatic washing machine, whose wash temperatures, amount of water, operation times, drum speed, reversing rhythm and wash steps order can be set, was used for the study. The temperature of pre-wash cycle was set at 30˚C. The drum speeds of machine were 50 rpm for washing steps and 60 rpm for rinsing steps. Rinsing was completed in two steps, both of which lasted five minutes. A reversing rhythm of 12 s of rotation / 4 s of pause was chosen for low wash liquor ratios (for cotton, cotton/polyester blend and polyester fabrics), and a reversing rhythm of 4 s of rotation / 12 s of pause was chosen for high liquor ratio (for wool and wool/polyester fabrics). Before washing, the soiled fabrics were cut into 5 cm × 5 cm pieces. The cut fabrics were stitched to a cotton fabric with dimensions of 70 cm × 100 cm. The total wash load was 1.5 kg, and the ballast load was 100% polyester fabric. Five different wash temperatures were chosen; 30, 40, 50, 60 and 80˚C. The wash

liquor ratios were 1:3 and 1:5. The main wash times were 10, 15, 20 and 25 minutes, and the 3 levels of pre-wash times were 0, 5 and 10 minutes.
Before and after washing, the colours of fabrics were measured by a Minolta CM-3600D spectrophotometer using a UV filter. Three measurements were made for each fabric. The reflectance values of fabrics at 460 nm were recorded. Soil removal from fabrics was calculated by subtracting reflectance values after washings from reflectance values before washings [8].

$$\Delta R = R_A - R_B \qquad \text{Eq.1}$$

R_A: Reflectance values after washings,
R_B: Reflectance values before washings,
ΔR: Amount of soil removal, the difference between R_A and R_B.
The results were evaluated according to variation analysis (α=0.05). Multiple comparisons between factor levels were evaluated according to the Duncan test.

RESULTS AND DISCUSSION

Results of washings at 30˚C

The results of soil removal depending on several factors at 30˚C are given in Table 4. For wool and wool/polyester blend fabrics, the only liquor ratio used was 1:10, because liquor ratios of 1:3 and 1:5 were not used for these fabrics in delicate programs of conventional washing machines. Again regarding conventional washing machines, pre-washing steps were not applied for these fabrics.
For removal of coke soil at 30˚C, the amount of soil removal increased with increasing liquor ratios for cotton fabrics, while for others it did not change. The main wash and pre-wash times had no effect on soil removal degree.
For removal of sour cherry juice soil, it was seen that the liquor ratio and the main wash times were effective for cotton fabric, but the pre-wash time had no effect on soil removal. The liquor ratios, main wash times and pre-wash times were not effective for cotton/polyester and polyester fabrics.
For all the fabrics soiled with instant coffee, the amount of soil removed increased with the increase in liquor ratios. Although soil removal increased with the increase in main wash times, different pre-wash times had no effect on the amount of soil removed.
The best soil removal was observed at a liquor ratio of 1:5 for fabrics soiled with sebum. Soil removal degree was variable depending on fibre types. For cotton fabrics, the soil removal degree increased with increasing liquor ratios, although for cotton/polyester blend and polyester fabrics, the soil removal degree decreased. It was demonstrated that main and pre-wash times had no significant effect on soil removal.

Results of washings at 40˚C

As seen in Table 5, for cotton and cotton/polyester fabrics soiled with coke, the highest soil removal degree was observed at the liquor ratio of 1:5. However, liquor ratios were not effective for polyester fabrics. It was demonstrated that main wash times had no significant effect on soil removal degree. Due to the increasing pre-wash times, the soil removal degree for cotton/polyester fabrics increased, although this had no effect on the other fabrics.
For the removal of sour cherry juice soil, the increase in the liquor ratios had no significant effect on the polyester fabric, although the soil removal degree increased with the increase in liquor ratios for the other fabrics. Regarding main wash times, the soil removal degree showed changes for cotton, cotton/polyester and wool/polyester fabrics, and it was demonstrated that the best result was observed at main wash times of 20 minutes.
Soil removal degree at liquor ratio of 1:5 was best for the fabrics soiled with instant coffee. The increase in the main wash times was significant for cotton, cotton/polyester and polyester fabrics, while it was not effective for wool and wool/polyester fabrics. For cotton and cotton/polyester fabrics, the soil removal degree increased with the increase in pre-wash times.
The best results of removing sebum soil at 40˚C were observed at a liquor ratio of 1:5 for all the fabrics. Regarding main and pre-wash times, soil removal degree increased with increasing time for all the fabrics.
For the removal of meat sauce soil, the liquor ratios did not show any significant effects. The main wash times were not effective for cotton fabrics, but they enhanced the soil removal degree for the other fabrics. Pre-wash times for all test fabrics were effective.

Table 4. Results of soil removal of washing at 30˚C

SOİL TYPE:	**COKE**	**FABRICS**				
Liquor Rstio		Co	Co/PES	PES	Wo	Wo/PES
	1_3	11.99	8.64	19.11		
	1_5	13.72	10.5	19.36		
	1_10				4.43	10.2
Main Wash Times						
	10 min	12.46	9.71	18.83	5.1	10.6
	15 min	13.16	9.26	19.08	3.89	10.14
	20 min	12.36	9.38	19.2	3.31	9.94
	25 min	13.46	9.93	19.83	5.43	10.12
Pre-wash Times						
	0	12.85	9.33	19.24	4.43	10.2
	5 min	12.95	9.41	18.92		
	10 min	12.78	9.98	19.53		
SOİL TYPE:SOUR CHERRY JUİCE		**FABRICS**				
Liquor Ratio		Co	Co/PES	PES	Wo	Wo/PES
	1_3	9.78	14.59	14.83		
	1_5	16.7	15.22	23.63		
	1_10				6.79	14.3
Main Wash Times						
	10 min	11.98	12.92	19.18	5.93	14.1
	15 min	12.2	15.67	18.33	6.94	13.99
	20 min	13.58	15.04	19.47	7.2	14.46
	25 min	15.19	15.99	19.95	7.1	14.68
Pre-wash Times						
	0	12.96	15.78	19.9	6.79	14.3
	5 min	13.32	12.6	18.37		
	10 min	13.44	16.35	19.42		
SOIL TYPE: INSTANT COFFEE		**FABRICS**				
Liquor Ratio		Co	Co/PES	PES	Wo	Wo/PES
	1_3	27.11	26.29	53.7		
	1_5	29.03	27.96	55.25		
	1_10				27.17	36.23
Main Wash Times						
	10 min	27.05	26.16	54.67	27.4	36.09
	15 min	26.69	26.08	53.91	25.58	36.7
	20 min	28.64	27.75	54.38	27.94	36.08
	25 min	29.89	28.51	54.95	27.78	36.04
Pre-wash Times						
	0	28.4	27.44	55.21	27.17	36.23
	5 min	27.72	26.49	53.98		
	10 min	28.09	27.44	54.24		
SOIL TYPE:	**SEBUM**	**FABRICS**				
Liquor astio		Co	Co/PES	PES	Wo	
	1_3	9.43	14.79	19.55		
	1_5	15.42	22.1	23.86		
	1_10				13.82	
Main Wash Times						
	10 min	10.96	16.08	19.57	12.16	
	15 min	11.93	16.52	21.53	14.98	
	20 min	13.15	19.63	22.3	14.52	
	25 min	13.66	21.55	23.43	13.63	
Pre-wash Times						
	0	11.55	17.53	20.66	13.82	
	5 min	13.05	18.11	21.87		
	10 min	12.68	19.69	22.59		
SOIL TYPE:	**MEAT SAUCE**	**FABRICS**				
Liquor Ratio		Co	Co/PES	PES	Wo	
	1_3	22.01	21.02	34.7		
	1_5	24.45	19.19	31.82		
	1_10				18.13	
Main Wash Times						
	10 min	22.27	20.09	32.8	16.25	
	15 min	23.31	18.44	32.91	17.24	
	20 min	23.15	20.92	33.41	17.64	
	25 min	24.18	20.98	33.92	21.4	
Pre-wash Times						
	0	22.38	20.3	33.18	18.13	
	5 min	23.33	19.02	32.63		
	10 min	23.98	21.01	33.96		

Table 5. Results of soil removal of washing at 40˚C

SOİL TYPE:	**COKE**	**FABRICS**				
Liquor Ratio		Co	Co/PES	PES	Wo	Wo/PES
	1_3	14.06	11.68	20.47		
	1_5	15.53	12.52	20.54		
	1_10	14.06	11.69	20.65	3.18	9,92
Main Wash Times						
	10 min	13.75	11.59	20.29	4.36	9,95
	15 min	14.11	11.79	20.17	4.85	11,33
	20 min	14.48	12.22	20.64	4.44	10,21
	25 min	14.61	12.27	21.12	3.09	8,21
Pre-wash Times						
	0	14.08	11.05	20.47	3.18	9,92
	5 min	14.44	12.16	20.52		
	10 min	14.18	12.69	20.68		
SOİL TYPE:SOUR CHERRY JUİCE		**FABRICS**				
Liquor Ratio		Co	Co/PES	PES	Wo	Wo/PES
	1_3	20.7	19.48	25.08		
	1_5	21.38	21.48	24.51		
	1_10	18.71	20.98	25.23	5.21	13,15
Main Wash Times						
	10 min	18.52	18.26	24.57	5.94	12,09
	15 min	20.07	19.37	24.88	5.97	13,5
	20 min	21.42	23.49	25.06	4.57	14,09
	25 min	21.02	21.48	25.25	4.36	12,93
Pre-wash Times						
	0	18.45	19.73	24.67	5.21	13,15
	5 min	21.68	22.34	25.23		
	10 min	20.65	19.88	24.92		
SOIL TYPE: INSTANT COFFEE		**FABRICS**				
Liquor Ratio		Co	Co/PES	PES	Wo	Wo/PES
	1_3	34.6	30.93	55.66		
	1_5	37.06	32.84	56.06		
	1_10	33.5	30.15	55.66	26.13	35,35
Main Wash Times						
	10 min	31.88	29.4	55.16	26.25	35,13
	15 min	34.64	31.02	55.39	25.86	35,91
	20 min	36.47	31.7	56.36	26.57	35,69
	25 min	37.23	33.09	56.27	25.84	34,69
Pre-wash Times						
	0	32.5	29.49	55.44	26.13	35,35
	5 min	36.3	31.37	56.15		
	10 min	36.36	33.05	55.79		
SOIL TYPE:	**SEBUM**	**FABRICS**				
Liquor Ratio		Co	Co/PES	PES	Wo	
	1_3	14.63	21.21	22.01		
	1_5	15.88	25.27	24.2		
	1_10	12.41	22.45	22.58	17.72	
Main Wash Times						
	10 min	11.47	19.32	21.37	14.28	
	15 min	13.45	22.13	21.85	16.96	
	20 min	15.48	24.41	23.62	19.65	
	25 min	16.83	26.04	24.89	19.99	
Pre-wash Times						
	0	12.26	18.77	20.78	17.72	
	5 min	14.73	24.73	23.93		
	10 min	15.93	25.42	24.08		
SOIL TYPE:	**MEAT SAUCE**	**FABRICS**				
Liquor Ratio		Co	Co/PES	PES	Wo	
	1_3	22.55	22.01	31.58		
	1_5	22.03	20.26	32.36		
	1_10	28.11	21.02	31.63	25.48	
Main Wash Times						
	10 min	23.77	19.51	31.36	24.52	
	15 min	24.77	19.98	31.45	27.34	
	20 min	24.47	22.38	32.21	26.57	
	25 min	23.85	22.53	32.4	23.48	
Pre-wash Times						
	0	18.66	21.32	30.75	25.48	
	5 min	27.18	20.87	32.37		
	10 min	26.85	21.11	32.45		

Table 6. Results of soil removal of washing at 50˚C

SOİL TYPE:	**COKE**	**FABRICS**		
Liquor Ratio		Co	Co/PES	PES
	1_3	14.47	11.39	19.08
	1_5	15.84	14.35	19.87
Main Wash Times				
	10 min	15.04	12.62	19.56
	15 min	14.57	12.86	19.27
	20 min	15.7	13.01	19.38
	25 min	15.28	12.97	19.68
Pre-wash Times				
	0	14.82	12.37	19.9
	5 min	15.04	13.53	19.37
	10 min	15.6	12.7	19.15
SOİL TYPE:SOUR CHERRY JUİCE		**FABRICS**		
Liquor Ratio		Co	Co/PES	PES
	1_3	24.02	25.86	26.46
	1_5	27.2	26.24	27.24
Main Wash Times				
	10 min	25.38	24.81	26.8
	15 min	25.65	26	26.88
	20 min	26.16	26.72	27.38
	25 min	25.24	26.68	26.35
Pre-wash Times				
	0	25.64	25.12	26.84
	5 min	26.23	27.27	26.76
	10 min	24.96	25.76	26.96
SOIL TYPE: INSTANT COFFEE		**FABRICS**		
Liquor Ratio		Co	Co/PES	PES
	1_3	40.54	37.4	56.04
	1_5	45.36	40	56.89
Main Wash Times				
	10 min	40.35	37.71	56.19
	15 min	42.49	38.66	56.3
	20 min	45.65	40.03	56.86
	25 min	43.31	38.39	56.51
Pre-wash Times				
	0	40.72	37.64	55.73
	5 min	44.42	39.42	57.24
	10 min	43.71	39.04	56.42
SOIL TYPE:	**SEBUM**	**FABRICS**		
Liquor Ratio		Co	Co/PES	PES
	1_3	24.35	31.22	27.23
	1_5	23.93	33.35	28.49
Main Wash Times				
	10 min	22.15	29.85	26.97
	15 min	23.59	32.04	27.95
	20 min	25.62	34.83	28.77
	25 min	25.2	32.43	27.77
Pre-wash Times				
	0	21.9	30.06	27.05
	5 min	24.23	32.81	28.19
	10 min	26.28	33.99	28.36
SOIL TYPE:	**MEAT SAUCE**	**FABRICS**		
Liquor Ratio		Co	Co/PES	PES
	1_3	24.98	22.24	34.31
	1_5	26.17	22.85	33.74
Main Wash Times				
	10 min	25.99	22.11	34.01
	15 min	25.33	22.69	33.62
	20 min	25.4	22.86	34.35
	25 min	25.58	22.51	34.11
Pre-wash Times				
	0	24.44	21.69	34.1
	5 min	25.59	22.66	33.84
	10 min	26.69	23.29	34.13

Table 7. Results of soil removal of washing at 60˚C

SOİL TYPE:	**COKE**	**FABRICS**		
Liquor Ratio		Co	Co/PES	PES
	1_3	15.02	11.74	20.03
	1_5	15.66	12.72	20.08
Main Wash Times				
	10 min	14.74	11.62	20.2
	15 min	15.25	12.32	19.99
	20 min	15.68	12.36	20.31
	25 min	15.7	12.63	19.72
Pre-wash Times				
	0	14.53	10.66	20.07
	5 min	15.3	12.92	20.35
	10 min	16.2	13.12	19.74
SOİL TYPE:SOUR CHERRY JUİCE		**FABRICS**		
Liquor Ratio		Co	Co/PES	PES
	1_3	20.74	21.14	23.7
	1_5	25.51	26.93	25.16
Main Wash Times				
	10 min	22.53	24.18	23.92
	15 min	23.33	24.02	23.98
	20 min	23.5	23.77	25.18
	25 min	23.15	24.18	24.63
Pre-wash Times				
	0	21.99	23.98	24.39
	5 min	24.13	24.96	24.85
	10 min	23.27	23.17	24.05
SOIL TYPE: INSTANT COFFEE		**FABRICS**		
Liquor Ratio		Co	Co/PES	PES
	1_3	40.12	36.94	56.1
	1_5	45.94	40.15	56.81
Main Wash Times				
	10 min	41.07	37.22	55.64
	15 min	43.06	38.69	56.62
	20 min	43.94	39.15	56.92
	25 min	44.05	39.13	56.65
Pre-wash Times				
	0	37.52	35.94	55.1
	5 min	45.56	40.42	57.07
	10 min	46.01	39.28	57.21
SOIL TYPE:	**SEBUM**	**FABRICS**		
Liquor Ratio		Co	Co/PES	PES
	1_3	23.74	29.69	27.39
	1_5	27.38	33.23	29
Main Wash Times				
	10 min	23.72	29.18	27.4
	15 min	24.55	32.18	28.29
	20 min	26.77	31.7	28.38
	25 min	27.2	32.78	28.71
Pre-wash Times				
	0	21.16	26.73	25.52
	5 min	28.16	33.39	29.42
	10 min	27.35	34.26	29.64
SOIL TYPE:	**MEAT SAUCE**	**FABRICS**		
Liquor Ratio		Co	Co/PES	PES
	1_3	24.66	22.72	34.75
	1_5	29.9	24.09	35.26
Main Wash Times				
	10 min	27.14	23.16	34.6
	15 min	28.25	23.26	34.98
	20 min	27.04	23.61	35.05
	25 min	26.7	23.6	35.39
Pre-wash Times				
	0	24.2	21.84	34.31
	5 min	29.72	24.3	35.42
	10 min	27.92	24.08	35.29

Table 8. Results of soil removal of washing at 80˚C

SOİL TYPE:	**COKE**	**FABRICS**		
Liquor Ratio		Co	Co/PES	PES
	1_3	15.48	13.79	19.86
	1_5	15.87	14.55	19.44
Main Wash Times				
	10 min	15.59	13.94	20.11
	15 min	15.18	13.92	19.6
	20 min	15.99	13.96	19.59
	25 min	15.93	14.82	19.3
Pre-wash Times				
	0	16.07	13.93	19.8
	5 min	15.74	14.7	19.21
	10 min	15.21	13.85	19.94
SOİL TYPE:SOUR CHERRY JUİCE		**FABRICS**		
Liquor Ratio		Co	Co/PES	PES
	1_3	20.21	13.63	19.42
	1_5	22.85	21.71	22.38
Main Wash Times				
	10 min	20.71	17.21	20.29
	15 min	21.87	17.47	20.95
	20 min	21.99	18.14	20.77
	25 min	21.55	17.86	21.59
Pre-wash Times				
	0	20.35	17.64	20.55
	5 min	22.37	17.58	21.73
	10 min	21.87	17.79	20.42
SOIL TYPE: INSTANT COFFEE		**FABRICS**		
Liquor Ratio		Co	Co/PES	PES
	1_3	42.63	36.44	54.9
	1_5	48.25	41.94	57.07
Main Wash Times				
	10 min	43.74	37.87	55.54
	15 min	45.31	39.48	56.32
	20 min	46.67	39.74	55.41
	25 min	46.05	39.66	56.65
Pre-wash Times				
	0	43.11	38.03	56.42
	5 min	46.52	39.61	55.23
	10 min	46.69	39.93	56.3
SOIL TYPE:	**SEBUM**	**FABRICS**		
Liquor Ratio		Co	Co/PES	PES
	1_3	25.58	29.34	28.49
	1_5	28.8	34.08	30.48
Main Wash Times				
	10 min	24.2	29.82	28.59
	15 min	27.86	31.44	29.2
	20 min	28.15	32.28	30
	25 min	28.54	33.31	30.15
Pre-wash Times				
	0	24.89	29.24	28.11
	5 min	27.59	33.12	30.48
	10 min	29.09	32.77	29.87
SOIL TYPE:	**MEAT SAUCE**	**FABRICS**		
Liquor Ratio		Co	Co/PES	PES
	1_3	28.88	25.16	36.47
	1_5	29.85	25.57	35.5
Main Wash Times				
	10 min	26.99	24.37	35.94
	15 min	28.5	25.21	36.08
	20 min	30.31	25.84	35.6
	25 min	31.67	26.03	36.32
Pre-wash Times				
	0	27.47	24.65	35.24
	5 min	30.47	25.92	36.16
	10 min	30.16	25.52	36.55

Results of washings at 50˚C

In Table 6, the soil removal results of washings at 50˚C are seen. There are no wool and wool/polyester fabrics at tables of washings at temperatures of 50˚C and above. These fabrics were washed only at the temperatures of 30 and 40˚C, which are harmless for wool.
Washings at 50˚C showed that soil removal degree increased as the liquor ratios for removing coke soil increased. Pre-wash and main wash times had a significant effect on coke soil removal.
Soil removal degree increased due to the increasing liquor ratios for the test samples soiled with sour cherry juice. Main wash times had no effect on soil removal. The best results were observed at the pre-wash time of 5 minutes for cotton and cotton/polyester fabrics, but pre-wash times had no effect on soil removal for polyester fabric.
It was demonstrated that the liquor ratios were effective at removing the instant coffee soil for cotton/polyester fabric. Main wash times were effective, and the best result was observed at the main wash time of 20 minutes for cotton and cotton/polyester fabrics. A pre-wash time of 5 minutes gave the best soil removal result for all fabrics.
For fabrics soiled with sebum, an increase in the liquor ratios increased the soil removal degree for cotton/polyester and polyester fabrics, while it had no effect on cotton fabric. For the main wash times, the best soil removal result was observed at 20 minutes. The soil removal of sebum soil increased with the increase in pre-wash times.
For polyester and cotton/polyester fabrics, soil was removed better with a higher liquor ratio, but for cotton fabric it had no effect on soil removal. It was demonstrated that the main wash time of 20 minutes gave the best result. The amount of soil removal increased with the increase in pre-wash times.
The amount of removal of meat sauce soil increased due to the increase in the liquor ratios for cotton and cotton/polyester fabrics. It was seen that main wash times had no effect on soil removal. Because of the increase in the pre-wash times, soil removal increased for all test samples.

Results of washings at 60˚C

As seen in Table 7, removal of coke soil increased by increasing liquor ratios at 60˚C for all three types of fabrics. The increase in main wash times caused an increase in the soil removal degree for cotton and cotton/polyester blend fabrics. However, it was not effective for polyester fabric. Soil removal degree increased with increasing pre-wash times, although these times had no effect on soil removal.
The removal of sour cherry juice soil increased with the increase in liquor ratios for all fabrics. Main wash times had no effect on the removal of sour cherry juice soil. For all fabrics, 5 minutes were the best result with respect to pre-wash times.
The amount of instant coffee soil removal at 60˚C increased with the increase in liquor ratios. In none of the test samples did the soil removal degree change with the change in main wash times. Regarding the effects of pre-washings, for cotton and cotton/polyester fabrics, the best result of soil removal was observed at 5 minutes of pre-wash time, while for the polyester fabric the soil removal degree increased with the increase in pre-wash times.
It was demonstrated that thanks to the increasing liquor ratios, sebum soil removal increased for all fabrics. Removal of sebum increased because of the increase in the main wash times. There is no difference in soil removal between the pre-wash times of 5 and 10 minutes; a 5-minute pre-wash is sufficient.
The degree of removal of meat sauce soil increased with the increase in liquor ratios. Main wash times had no effect on soil removal degree for all fabrics. When we examine pre-wash times on soil removal, the best result was obtained with a 5-minute pre-wash time for all the test fabrics.

Results of washings at 80˚C

When we consider soil removal results at 80˚C in Table 8, changes in liquor ratio, main wash times and pre-wash times had no effect on coke soil removal for all the test fabrics.
Removal of sour cherry juice soil increased with the increase in liquor ratios for all the fabrics. Changes in main wash times had no effect on soil removal. The best results was obtained at a 5-minute pre-wash time for cotton and polyester fabrics, although pre-wash times had no effect on cotton/polyester fabric.

The effect of instant coffee soil removal increased with the increase in liquor ratios. Changes in main wash times had no significant effect on the removal of instant coffee soil at 80˚C. Soil removal degree increased for cotton and cotton/polyester fabrics due to the increase in pre-wash times.
Sebum soil removal degree increased with increasing liquor ratios. It was seen that sebum was better removed due to the increasing main wash times. Regarding pre-wash times, soil removal increased with the increase in time for cotton fabric, as a 5-minute pre-wash time gave the best result for other fabrics.
Liquor ratios had no effect on meat sauce soil removal for all the fabrics except polyester fabric. Soil removal was better at a liquor ratio of 1:3 for polyester fabric. Soil removal increased with increasing main wash times for cotton and cotton/polyester fabrics; however, it did not change for polyester fabric. Regarding main wash times, the best result was observed at 25 minutes for all the fabrics. A 5-minute pre-wash time gave the best results for cotton and cotton/polyester fabrics. Regarding polyester fabric, soil removal degree increased with increasing pre-wash time.

Conclusion

Effective soil removal degrees are observed at very high temperatures and very long washing times by domestic washing machines. As a result of this, energy, water and detergent consumptions are extremely high. However, for some soils and textile materials, longer times, more water consumption and higher temperature may not be necessary.
In this study, it has been demonstrated that polyester is the best cleanable textile material. The reason for this is that polyester is a synthetic fibre, so it does not include natural pigments, and its whiteness is higher than the other fabrics. For instance, the difference between the colours of a polyester fabric soiled with coke soil and a clean, white polyester fabric is higher than the difference for all other fabrics made by other fibres. The difference for wool and wool/polyester blend fabrics is smaller because bleached wool fabric has a yellowy colour (écru).
Usually for all fabrics, pre-wash time may be chosen as 5 minutes, if necessary. While it is apparent that more soil removal degree is observed at liquor ratio of 1:5 for most fabrics and soils, the degree is decreased because of the lowering of the rubbing effect at the liquor ratio of 1:10.
For the cotton textile materials, at the pre-wash time of 5 minutes, the main wash time of 25 minutes and the liquor ratio of 1:5 may be suggested for the easily removable soils such as coke, and the pre-wash time of 10 minutes for the soils that are difficult to remove like sebum.
The most effective soil removal results at all the temperatures for cotton/polyester blend fabrics can be obtained at the liquor ratio of 1:5, the pre-wash time of 5 minutes and the main wash time of 25 minutes.
For polyester fabrics, the optimum liquor ratio is 1:5 and the optimum main wash time is 25 minutes at all temperatures. If it is not necessary, there need not be any pre-washing steps, because the soil removal values of the pre-wash times are not different.
For wool and wool/polyester fabrics, optimum main wash times are 20-25 minutes for 30˚C, and 15 minutes for 40˚C.
The results of this project will be a guide in designing machines which are programmable according to fibre type, and consume less energy and water during washings.

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References

1. *Morris, M.A. and Prato, H.H., Textile Research Journal,* ***1982****, 4, 280-285.*
2. *Cutler, W.G. and Kissa, E. (eds), Detergency: Theory and Technology,* ***1987****, Vol.20 of the Surfactant Science Series, Dekker, New York.*
3. *Jakobi, G., Löhr, A., Detergents and Textile Washing, Principles and Practice,* ***1987****, VCH, 204-221.*
4. *Cutler, W.G. and Davies, R.C. (eds), Detergency Theory and Test Methods, Part I.,* ***1972,*** *Vol.5 of Surfactant Science Series, Dekker, New York.*
5. *Cutler, W.G. and Davies, R.C. (eds), Detergency Theory and Test Methods, Part II.* ***1975****, Vol.5 of Surfactant Science Series, Dekker, New York.*

6. *Cutler, W.G. and Davies, R.C. (eds), Detergency Theory and Test Methods, Part III.* ***1981****, Vol.5 of Surfactant Science Series, Dekker, New York.*
7. *Bishop, D.P. in Chemistry of the Textiles Industry, (edited by C.M.Carr),* ***1995****, Blackie Academic &Professional, UK 124-171.*
8. *Paek, S.L., Journal of Textile Instıtute,* ***1987****, No. 1, 26-34.*

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