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## APPENDICES

### Appendix A Experimental Data of the Phase Diagrams

#### 1. Solubilization Parameter (SP)

The solubilization parameter of oil (SP<sub>o</sub>) and water (SP<sub>w</sub>) are designed as:

$$SP_o = \frac{V_o}{M_s} \quad \text{and} \quad SP_w = \frac{V_w}{M_s}$$

Where

- V<sub>o</sub> = volume of oil solubilized
- M<sub>s</sub> = weight of surfactants
- V<sub>w</sub> = volume of water solubilized

#### 2. Interfacial Tension (IFT)

The interfacial tension of each phase of microemulsion is calculated by following formulation:

$$IFT = e(Vd)^3 n^2 \Delta\rho$$

Where

- IFT = interfacial tension (mN/m)
- V = 0.31 (mm/sdv)
- e = 3.427x10<sup>-4</sup> (mN cm<sup>3</sup> min<sup>2</sup>/m g mm<sup>3</sup>)
- d = diameter of the measured droplet (sdv)
- n = number of revolution or speed (rpm)
- Δρ = the density difference between the heavy phase and the light phase (g/cm<sup>3</sup>)



### 3. Experiment Data of Solubilization Parameter

**Table A-1** Solubilization parameter of oil and water phase in microemulsion formation with 0.1wt% Alfoterra 145-3PO and 5wt% Tergitol 15S5 at different NaCl concentrations with hardness 0 ppm and 100 ppm by using oil to water ratio of 1:1

Hardness (ppm)	NaCl (%w/v)	Phase Height: Before (mm)			Phase Height at Equ.(mm)			Solubilization (mm)		Solubilization (ml)		Ms (g)	Solubilization	
		Water	Oil	Total	Water	Middle	Oil	Water	Oil	Water	Oil		Spw	Spo
0	0.1	33.88	33.78	67.66	35.79	0.00	31.87	33.88	1.91	4.9824	0.2809	0.2550	19.5386	1.1015
	0.5	34.08	33.86	67.94	35.87	0.00	32.03	34.04	1.83	5.0059	0.2691	0.2550	19.6309	1.0554
	1.0	33.51	34.68	68.19	35.68	0.00	32.50	33.50	2.18	4.9265	0.3206	0.2550	19.3195	1.2572
	1.5	33.74	34.00	67.74	36.33	0.00	31.45	33.78	2.55	4.9676	0.3750	0.2550	19.4810	1.4706
	2.0	34.52	30.45	64.97	37.91	0.00	27.13	34.59	3.32	5.0868	0.4882	0.2550	19.9481	1.9146
	3.0	33.83	31.36	65.19	22.47	12.25	30.58	11.36	0.78	1.6706	0.1147	0.2550	6.5513	0.4498
	4.0	33.02	32.09	65.11	24.43	15.58	24.92	8.59	7.17	1.2632	1.0544	0.2550	4.9539	4.1349
	5.0	33.74	31.48	65.22	27.24	16.26	21.78	6.50	9.70	0.9559	1.4265	0.2550	3.7486	5.5940
	10.0	33.51	34.26	67.77	30.23	0.00	37.56	3.28	26.95	0.4824	3.9632	0.2550	1.8916	15.5421
15.0	34.79	32.94	67.73	32.35	0.00	35.44	2.44	29.91	0.3588	4.3985	0.2550	1.4072	17.2491	
100	0.1	33.50	33.34	66.84	36.73	0.00	30.69	34.08	2.65	5.0118	0.3897	0.2550	19.6540	1.5283
	0.5	33.56	33.18	66.74	36.28	0.00	30.56	33.66	2.62	4.9500	0.3853	0.2550	19.4118	1.5110
	1.0	33.93	33.14	67.07	36.74	0.00	30.39	33.99	2.75	4.9985	0.4044	0.2550	19.6021	1.5859
	1.5	34.12	33.27	67.39	37.16	0.00	30.26	34.15	3.01	5.0221	0.4426	0.2550	19.6943	1.7359
	2.0	34.07	30.88	64.95	37.54	0.00	27.37	34.03	3.51	5.0044	0.5162	0.2550	19.6251	2.0242
	3.0	33.95	30.62	64.57	24.82	10.14	29.59	9.13	1.03	1.3426	0.1515	0.2550	5.2653	0.5940
	4.0	34.22	30.65	64.87	25.49	15.42	23.91	8.73	6.74	1.2838	0.9912	0.2550	5.0346	3.8870
	5.0	34.45	31.02	65.47	28.16	15.59	21.63	6.29	9.39	0.9250	1.3809	0.2550	3.6275	5.4152
	10.0	34.04	32.90	66.94	31.34	0.00	35.88	2.70	33.18	0.3971	4.8794	0.2550	1.5571	19.1349
	15.00	33.42	33.61	67.03	31.30	0.00	35.75	2.12	33.63	0.3118	4.9456	0.2550	1.2226	19.3945

**Table A-2** Solubilization parameter of oil and water phase in microemulsion formation with 0.1wt% Alfoterra 145-3PO and 5wt% Tergitol 15S5 at different NaCl concentrations with hardness 500 ppm and 1000 ppm by using oil to water ratio of 1:1

Hardness (ppm)	NaCl (%w/v)	Phase Height: Before (mm)			Phase Height at Equ.(mm)			Solubilization (mm)		Solubilization (ml)		Ms (g)	Solubilization	
		Water	Oil	Total	Water	Middle	Oil	Water	Oil	Water	Oil		Spw	Spo
500	0.1	33.21	33.35	66.56	35.65	0.00	31.02	33.32	2.33	4.9000	0.3426	0.2550	19.2157	1.3437
	0.5	34.02	32.60	66.62	36.73	0.00	30.00	34.13	2.60	5.0191	0.3824	0.2550	19.6828	1.4994
	1.0	33.71	33.37	67.08	36.74	0.00	30.50	33.87	2.87	4.9809	0.4221	0.2550	19.5329	1.6551
	1.5	33.78	32.99	66.77	37.24	0.00	29.72	33.97	3.27	4.9956	0.4809	0.2550	19.5905	1.8858
	2.0	34.20	31.02	65.22	38.42	0.00	26.79	34.19	4.23	5.0279	0.6221	0.2550	19.7174	2.4394
	3.0	34.49	30.77	65.26	25.55	9.90	29.72	8.94	1.05	1.3147	0.1544	0.2550	5.1557	0.6055
	4.0	35.08	30.37	65.45	26.52	15.21	23.81	8.56	6.56	1.2588	0.9647	0.2550	4.9366	3.7832
	5.0	33.75	31.48	65.23	27.58	16.85	20.82	6.17	10.66	0.9074	1.5676	0.2550	3.5582	6.1476
	10.0	34.22	33.41	67.63	31.20	0.00	36.58	3.02	33.56	0.4441	4.9353	0.2550	1.7416	19.3541
15.0	34.30	33.09	67.39	31.89	0.00	35.54	2.41	33.13	0.3544	4.8721	0.2550	1.3899	19.1061	
1000	0.1	34.19	33.08	67.27	36.12	0.00	31.22	34.26	1.86	5.0382	0.2735	0.2550	19.7578	1.0727
	0.5	34.17	33.33	67.50	36.46	0.00	31.21	34.34	2.12	5.0500	0.3118	0.2550	19.8039	1.2226
	1.0	34.88	32.52	67.40	37.74	0.00	29.81	35.03	2.71	5.1515	0.3985	0.2550	20.2018	1.5629
	1.5	34.08	32.82	66.90	37.03	0.00	30.06	34.27	2.76	5.0397	0.4059	0.2550	19.7636	1.5917
	2.0	33.86	31.51	65.37	39.47	0.00	25.86	33.82	5.65	4.9735	0.8309	0.2550	19.5040	3.2584
	3.0	33.80	32.49	66.29	25.73	9.11	31.47	8.07	1.02	1.1868	0.1500	0.2550	4.6540	0.5882
	4.0	34.17	31.51	65.68	26.93	15.44	23.18	7.24	8.33	1.0647	1.2250	0.2550	4.1753	4.8039
	5.0	33.93	31.48	65.41	27.98	18.97	18.53	5.95	12.95	0.8750	1.9044	0.2550	3.4314	7.4683
	10.0	35.69	31.62	67.31	32.14	0.00	35.16	3.55	28.59	0.5221	4.2044	0.2550	2.0473	16.4879
15.0	33.90	33.41	67.31	31.22	0.00	36.25	2.68	28.54	0.3941	4.1971	0.2550	1.5456	16.4591	

## Appendix B Experimental Data of The Microemulsion Diagrams (Fish Diagrams)

**Table B-1** Type of microemulsions with various %total mixed surfactant concentrations by using a mixed surfactant of 0.1wt% Alfoterra 145-3PO and 5wt% Tergitol 15S5 at different NaCl concentrations under the presence and absence of hardness by using oil to water ratio of 1:1

Total Mixed Surf. (%w/v)	NaCl (%w/v)	Type of Microemulsions			
		DI Water (Oppm)	Hardness 100ppm	Hardness 500ppm	Hardness 1000ppm
0.5	1	Type I	Type I	Type I	Type I
	2	Type I	Type I	Type I	Type I
	3	Type I	Type I	Type I	Type I
	4	Type III	Type III	Type III	Type III
	5	Type III	Type III	Type III	Type III
	6	Type II	Type II	Type II	Type II
	7	Type II	Type II	Type II	Type II
	8	Type II	Type II	Type II	Type II
	9	Type II	Type II	Type II	Type II
	10	Type II	Type II	Type II	Type II
1	1	Type I	Type I	Type I	Type I
	2	Type I	Type I	Type I	Type I
	3	Type I	Type I	Type I	Type I
	4	Type III	Type III	Type III	Type III
	5	Type III	Type III	Type III	Type III
	6	Type II	Type II	Type II	Type II
	7	Type II	Type II	Type II	Type II
	8	Type II	Type II	Type II	Type II
	9	Type II	Type II	Type II	Type II
	10	Type II	Type II	Type II	Type II
2	1	Type I	Type I	Type I	Type I
	2	Type I	Type I	Type I	Type I
	3	Type III	Type III	Type III	Type III
	4	Type III	Type III	Type III	Type III
	5	Type III	Type III	Type III	Type III
	6	Type II	Type II	Type II	Type II
	7	Type II	Type II	Type II	Type II
	8	Type II	Type II	Type II	Type II
	9	Type II	Type II	Type II	Type II
	10	Type II	Type II	Type II	Type II

**Table B-2** Type of microemulsions with various %total mixed surfactant concentrations by using a mixed surfactant of 0.1wt% Alfoterra 145-3PO and 5wt% Tergitol 15S5 at different NaCl concentrations under the presence and absence of hardness by using oil to water ratio of 1:1

Total Mixed Surf. (%w/v)	NaCl (%w/v)	Type of Microemulsion			
		DI Water (0ppm)	Hardness 100ppm	Hardness 500ppm	Hardness 1000ppm
3	1	Type I	Type I	Type I	Type I
	2	Type I	Type I	Type I	Type I
	3	Type III	Type III	Type III	Type III
	4	Type III	Type III	Type III	Type III
	5	Type III	Type III	Type III	Type III
	6	Type III	Type III	Type III	Type III
	7	Type III	Type III	Type III	Type III
	8	Type II	Type II	Type II	Type II
	9	Type II	Type II	Type II	Type II
	10	Type II	Type II	Type II	Type II
4	1	Type I	Type I	Type I	Type I
	2	Type I	Type I	Type I	Type I
	3	Type III	Type III	Type III	Type III
	4	Type III	Type III	Type III	Type III
	5	Type III	Type III	Type III	Type III
	6	Type III	Type III	Type III	Type III
	7	Type III	Type III	Type III	Type III
	8	Type II	Type II	Type II	Type II
	9	Type II	Type II	Type II	Type II
	10	Type II	Type II	Type II	Type II
5.1	1	Type I	Type I	Type I	Type I
	2	Type I	Type I	Type I	Type I
	3	Type III	Type III	Type III	Type III
	4	Type III	Type III	Type III	Type III
	5	Type III	Type III	Type III	Type III
	6	Type III	Type III	Type III	Type III
	7	Type III	Type III	Type III	Type III
	8	Type III	Type III	Type III	Type III
	9	Type II	Type II	Type II	Type II
	10	Type II	Type II	Type II	Type II

## Appendix C Experimental Data of Detergency Experiments

### 1. %Detergency

The detergency performance can be determined by %detergency. It is calculated from the following equation:

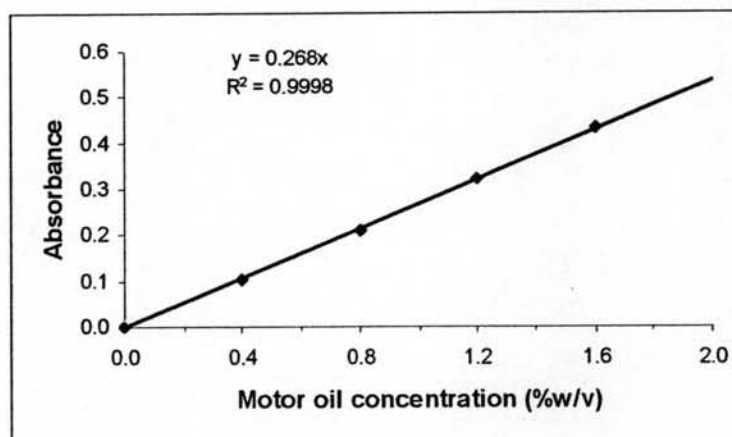
$$\%Detergency = [(A - B)/(C_0 - B)] \times 100$$

Where

- A = the average reflectance of the soiled swatches after washing
- B = the average reflectance of the soiled swatches before washing
- C<sub>0</sub> = the average reflectance of the unsoiled swatches before washing

### 2. %Oil Removal

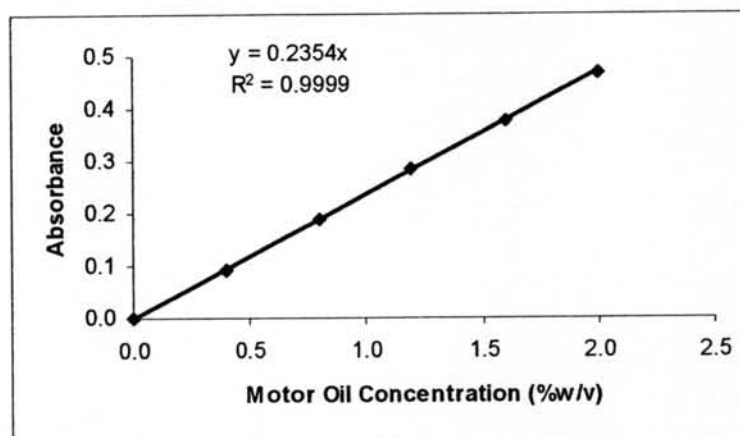
The oil removal is calculated from the calibration curve for colored motor oil



**Figure C-1** Relationship between colored motor oil concentration (%w/v) and the absorbance measured at 520 nm by using iso-propanol as solvent.

**Table C-1** Relationship between colored motor oil concentration (%w/v) and the absorbance measured at 520 nm by using iso-propanol as solvent

No.	[Motor Oil] %w/v	Absorbance
1	0.00	0.000
2	0.40	0.104
3	0.80	0.211
4	1.20	0.322
5	1.60	0.431



**Figure C-2** Relationship between colored motor oil concentration (%w/v) and the absorbance measured at 520 nm by using dichloromethane as solvent.

**Table C-2** Relationship between colored motor oil concentration (%w/v) and the absorbance measured at 520 nm by using dichloromethane as solvent

No.	[Motor Oil] %w/v	Absorbance
1	0.00	0.000
2	0.40	0.093
3	0.80	0.188
4	1.20	0.285
5	1.60	0.376
6	2.00	0.470

### 3. Experimental Data of Detergency Experiment

#### 3.1 Effect of Hardness on Detergency Performance

**Table C-3** Initial oily soil concentration (%w/v) on the cotton fabric extracted by iso-propanol 50 ml/time

Type of Fabric	Fabric	[Initial Oily Soil] / Solution 50 ml (%w/v)			[Initial Soil] Avg. / 50 ml (%w/v)
		No.1	No.2	Total	
Cotton	1C1-12	2.368	0.146	2.514	2.530
	2C1-12	2.443	0.133	2.576	
	3C1-12	2.367	0.133	2.500	
	1C13-24	2.419	0.161	2.580	2.571
	2C13-24	2.418	0.152	2.570	
	3C13-24	2.382	0.182	2.564	
	1C25-36	2.439	0.212	2.651	2.605
	2C25-36	2.419	0.200	2.619	
	3C25-36	2.376	0.170	2.546	
	1C37-48	2.432	0.160	2.592	2.606
	2C37-48	2.461	0.181	2.642	
	3C37-48	2.415	0.170	2.585	

**Table C-4** %Oil removal on the cotton fabric after washing

Hardness (ppm)	%NaCl	Fabric	[Residue Oil] / Solution 50 ml (%w/v)			Oil Removal / 50 ml (%w/v)	% Oil Removal	% Oil Removal Avg.
			No.1	No.2	Total			
0	2	C1	0.643	0.130	0.773	1.757	69.447	67.787
		C2	0.749	0.120	0.869	1.661	65.652	
		C3	0.681	0.122	0.803	1.727	68.261	
	4	C4	0.460	0.110	0.570	1.960	77.470	77.668
		C5	0.450	0.104	0.554	1.976	78.103	
		C6	0.470	0.101	0.571	1.959	77.431	
	5	C7	0.206	0.128	0.334	2.196	86.798	85.059
		C8	0.262	0.145	0.407	2.123	83.913	
		C9	0.262	0.131	0.393	2.137	84.466	
	10	C10	0.180	0.125	0.305	2.225	87.945	88.682
		C11	0.170	0.104	0.274	2.256	89.170	
		C12	0.160	0.120	0.280	2.250	88.933	

**Table C-5** %Oil removal on the cotton fabric by using a mixed surfactant of 0.1wt% Alfoterra 145-3PO and 5wt% Tergitol 15S5 at different NaCl concentrations under the presence and absence of hardness and using iso-propanol as solvent

Hardness (ppm)	%NaCl	Fabric	[Residue Oil] / Solution 50 ml (%w/v)			Oil Removal / 50 ml (%w/v)	% Oil Removal	% Oil Removal Avg.
			No.1	No.2	Total			
100	2	C13	1.502	0.144	1.646	0.925	35.978	35.537
		C14	1.510	0.143	1.653	0.918	35.706	
		C15	1.541	0.132	1.673	0.898	34.928	
	4	C16	1.147	0.165	1.312	1.259	48.969	48.528
		C17	1.138	0.178	1.316	1.255	48.814	
		C18	1.159	0.183	1.342	1.229	47.802	
	5	C19	1.065	0.145	1.210	1.361	52.937	53.390
		C20	1.039	0.151	1.190	1.381	53.715	
		C21	1.053	0.142	1.195	1.376	53.520	
	10	C22	0.985	0.100	1.085	1.486	57.799	58.084
		C23	0.950	0.104	1.054	1.517	59.004	
		C24	0.976	0.118	1.094	1.477	57.448	
500	2	C25	1.729	0.257	1.986	0.619	23.762	23.301
		C26	1.735	0.236	1.971	0.634	24.338	
		C27	1.798	0.239	2.037	0.568	21.804	
	4	C28	1.234	0.184	1.418	1.187	45.566	45.234
		C29	1.243	0.187	1.430	1.175	45.106	
		C30	1.251	0.181	1.432	1.173	45.029	
	5	C31	1.142	0.180	1.322	1.283	49.251	49.699
		C32	1.130	0.173	1.303	1.302	49.981	
		C33	1.124	0.182	1.306	1.299	49.866	
	10	C34	0.923	0.160	1.083	1.522	58.426	56.545
		C35	1.006	0.165	1.171	1.434	55.048	
		C36	0.971	0.171	1.142	1.463	56.161	
1000	2	C37	1.928	0.257	2.185	0.421	16.155	16.999
		C38	1.885	0.249	2.134	0.472	18.112	
		C39	1.872	0.298	2.170	0.436	16.731	
	4	C40	1.472	0.235	1.707	0.899	34.497	35.661
		C41	1.425	0.213	1.638	0.968	37.145	
		C42	1.456	0.229	1.685	0.921	35.342	
	5	C43	1.279	0.243	1.522	1.084	41.596	41.225
		C44	1.297	0.241	1.538	1.068	40.982	
		C45	1.285	0.250	1.535	1.071	41.097	
	10	C46	1.129	0.204	1.333	1.273	48.849	48.593
		C47	1.141	0.213	1.354	1.252	48.043	
		C48	1.121	0.211	1.332	1.274	48.887	



**Table C-6** Initial oily soil concentration (%w/v) on the polyester/ cotton (65/35) blend fabric extracted by iso-propanol 50 ml/time

Type of Fabric	Fabric	[Initial Oily Soil] / Solution 50 ml (%w/v)			[Initial Soil] Avg. / 50 ml (%w/v)
		No.1	No.2	Total	
Blend	1B1-12	1.998	0.119	2.117	2.103
	2B1-12	1.972	0.095	2.067	
	3B1-12	2.024	0.101	2.125	
	1B13-24	2.163	0.119	2.282	2.220
	2B13-24	2.057	0.095	2.152	
	3B13-24	2.124	0.101	2.225	
	1B25-36	1.988	0.119	2.107	2.188
	2B25-36	2.107	0.095	2.202	
	3B25-36	2.154	0.101	2.255	
	1B37-48	2.087	0.119	2.206	2.139
	2B37-48	1.992	0.095	2.087	
	3B37-48	2.024	0.101	2.125	

**Table C-7** %Oil removal on the polyester/ cotton (65/35) blend fabric after washing by using a mixed surfactant of 0.1wt% Alfoterra 145-3PO and 5wt% Tergitol 15S5 at different NaCl concentrations under the presence and absence of hardness and using iso-propanol as solvent

Hardness (ppm)	%NaCl	Fabric	[Residue Oil] / Solution 50 ml (%w/v)			Oil Removal / 50 ml (%w/v)	% Oil Removal	% Oil Removal Avg.
			No.1	No.2	Total			
0	2	B1	0.724	0.027	0.751	1.352	64.289	65.002
		B2	0.702	0.028	0.730	1.373	65.288	
		B3	0.698	0.029	0.727	1.376	65.430	
	4	B4	0.561	0.035	0.596	1.507	71.660	73.498
		B5	0.492	0.047	0.539	1.564	74.370	
		B6	0.499	0.038	0.537	1.566	74.465	
	5	B7	0.338	0.031	0.369	1.734	82.454	82.057
		B8	0.354	0.032	0.386	1.717	81.645	
		B9	0.348	0.029	0.377	1.726	82.073	
	10	B10	0.280	0.012	0.292	1.811	86.115	85.846
		B11	0.284	0.012	0.296	1.807	85.925	
		B12	0.291	0.014	0.305	1.798	85.497	

**Table C-8** %Oil removal on the polyester/ cotton (65/35) blend fabric after washing by using a mixed surfactant system at different NaCl concentrations under the presence and absence of hardness and using iso-propanol as solvent

Hardness (ppm)	%NaCl	Fabric	[Residue Oil] / Solution 50 ml (%w/v)			Oil Removal / 50 ml (%w/v)	% Oil Removal	% Oil Removal Avg.
			No.1	No.2	Total			
100	2	B13	1.396	0.047	1.443	0.777	35.000	32.538
		B14	1.547	0.046	1.593	0.627	28.243	
		B15	1.408	0.049	1.457	0.763	34.369	
	4	B16	0.993	0.044	1.037	1.183	53.293	45.887
		B17	0.974	0.051	1.025	1.195	53.829	
		B18	1.488	0.054	1.542	0.678	30.541	
	5	B19	0.992	0.034	1.026	1.194	53.784	50.646
		B20	1.080	0.033	1.113	1.107	49.865	
		B21	1.118	0.030	1.148	1.072	48.288	
	10	B22	0.945	0.023	0.968	1.252	56.396	55.000
		B23	0.948	0.025	0.973	1.247	56.171	
		B24	1.028	0.028	1.056	1.164	52.432	
500	2	B25	1.599	0.053	1.652	0.536	24.497	22.197
		B26	1.688	0.052	1.740	0.448	20.475	
		B27	1.657	0.058	1.715	0.473	21.618	
	4	B28	1.187	0.051	1.238	0.950	43.419	42.992
		B29	1.224	0.052	1.276	0.912	41.682	
		B30	1.177	0.051	1.228	0.960	43.876	
	5	B31	1.157	0.022	1.179	1.009	46.115	46.009
		B32	1.154	0.023	1.177	1.011	46.207	
		B33	1.160	0.028	1.188	1.000	45.704	
	10	B34	1.102	0.041	1.143	1.045	47.761	50.000
		B35	1.058	0.040	1.098	1.090	49.817	
		B36	0.995	0.046	1.041	1.147	52.422	
1000	2	B37	1.701	0.044	1.745	0.394	18.420	14.898
		B38	1.774	0.041	1.815	0.324	15.147	
		B39	1.855	0.046	1.901	0.238	11.127	
	4	B40	1.461	0.037	1.498	0.641	29.967	30.014
		B41	1.468	0.042	1.510	0.629	29.406	
		B42	1.451	0.032	1.483	0.656	30.669	
	5	B43	1.150	0.041	1.191	0.948	44.320	40.003
		B44	1.305	0.040	1.345	0.794	37.120	
		B45	1.269	0.045	1.314	0.825	38.569	
	10	B46	1.131	0.032	1.163	0.976	45.629	46.003
		B47	1.104	0.032	1.136	1.003	46.891	
		B48	1.123	0.043	1.166	0.973	45.489	

**Table C-9** Initial oily soil concentration (%w/v) on the polyester fabric extracted by iso-propanol 50 ml/time

Type of Fabric	Fabric	[Initial Oily Soil] / Solution 50 ml (%w/v)			[Initial Soil] Avg. / 50 ml (%w/v)
		No.1	No.2	Total	
Polyester	1P1-12	1.62	0.107	1.727	1.649
	2P1-12	1.533	0.077	1.61	
	3P1-12	1.528	0.082	1.61	
	1P13-24	1.663	0.06	1.723	1.692666667
	2P13-24	1.568	0.048	1.616	
	3P13-24	1.674	0.065	1.739	
	1P25-36	1.592	0.075	1.667	1.687333333
	2P25-36	1.602	0.096	1.698	
	3P25-36	1.601	0.096	1.697	
	1P37-48	1.604	0.075	1.679	1.677666667
	2P37-48	1.598	0.096	1.694	
	3P37-48	1.564	0.096	1.66	

**Table C-10** %Oil removal on the polyester fabric after washing by using a mixed surfactant of 0.1wt% Alfoterra 145-3PO and 5wt% Tergitol 15S5 at different NaCl concentrations under the presence and absence of hardness and using iso-propanol as solvent

Hardness (ppm)	%NaCl	Fabric	[Residue Oil] / Solution 50 ml (%w/v)			Oil Removal / 50 ml (%w/v)	% Oil Removal	% Oil Removal Avg.
			No.1	No.2	Total			
0	2	P1	0.743	0.018	0.761	0.888	53.851	55.751
		P2	0.680	0.017	0.697	0.952	57.732	
		P3	0.714	0.017	0.731	0.918	55.670	
	4	P4	0.399	0.027	0.426	1.223	74.166	74.146
		P5	0.413	0.023	0.436	1.213	73.560	
		P6	0.398	0.019	0.417	1.232	74.712	
	5	P7	0.285	0.015	0.300	1.349	81.807	80.736
		P8	0.263	0.023	0.286	1.363	82.656	
		P9	0.348	0.019	0.367	1.282	77.744	
	10	P10	0.256	0.015	0.271	1.378	83.566	83.990
		P11	0.246	0.013	0.259	1.390	84.294	
		P12	0.243	0.019	0.262	1.387	84.112	

**Table C-11** %Oil removal on the polyester fabric after washing by using a mixed surfactant system at different NaCl concentrations under the presence and absence of hardness and using iso-propanol as solvent

Hardness (ppm)	%NaCl	Fabric	[Residue Oil] / Solution 50 ml (%w/v)			Oil Removal / 50 ml (%w/v)	% Oil Removal	% Oil Removal Avg.
			No.1	No.2	Total			
100	2	P13	1.118	0.057	1.175	0.518	30.583	30.228
		P14	1.115	0.058	1.173	0.520	30.701	
		P15	1.137	0.058	1.195	0.498	29.401	
	4	P16	0.943	0.042	0.985	0.708	41.808	43.245
		P17	0.934	0.042	0.976	0.717	42.340	
		P18	0.858	0.063	0.921	0.772	45.589	
	5	P19	0.841	0.042	0.883	0.810	47.834	48.976
		P20	0.820	0.044	0.864	0.829	48.956	
		P21	0.791	0.053	0.844	0.849	50.138	
	10	P22	0.771	0.027	0.798	0.895	52.855	52.580
		P23	0.795	0.022	0.817	0.876	51.733	
		P24	0.772	0.021	0.793	0.900	53.151	
500	2	P25	1.279	0.061	1.340	0.347	20.585	20.150
		P26	1.288	0.059	1.347	0.340	20.170	
		P27	1.297	0.058	1.355	0.332	19.696	
	4	P28	0.973	0.042	1.015	0.672	39.846	40.932
		P29	0.991	0.042	1.033	0.654	38.779	
		P30	0.891	0.051	0.942	0.745	44.172	
	5	P31	0.909	0.020	0.929	0.758	44.943	44.093
		P32	0.918	0.035	0.953	0.734	43.520	
		P33	0.917	0.031	0.948	0.739	43.817	
	10	P34	0.839	0.047	0.886	0.801	47.491	50.000
		P35	0.773	0.038	0.811	0.876	51.936	
		P36	0.795	0.039	0.834	0.853	50.573	
1000	2	P37	1.405	0.047	1.452	0.226	13.451	14.365
		P38	1.384	0.049	1.433	0.245	14.584	
		P39	1.377	0.048	1.425	0.253	15.061	
	4	P40	1.167	0.057	1.224	0.454	27.042	27.379
		P41	1.186	0.048	1.234	0.444	26.445	
		P42	1.139	0.058	1.197	0.481	28.651	
	5	P43	0.943	0.042	0.985	0.693	41.288	38.605
		P44	1.078	0.042	1.120	0.558	33.241	
		P45	0.942	0.043	0.985	0.693	41.288	
	10	P46	0.927	0.042	0.969	0.709	42.241	40.473
		P47	0.954	0.042	0.996	0.682	40.632	
		P48	0.968	0.063	1.031	0.647	38.546	

### 3.2 Effect of Builders on Detergency Performance

**Table C-12** Initial oily soil concentration (%w/v) on the cotton fabric extracted by iso-propanol 50 ml/time

Type of Fabric	Fabric	[Initial Oily Soil] / Solution 50 ml (%w/v)			[Initial Soil] Avg. / 50 ml (%w/v)
		No.1	No.2	Total	
Cotton	1cs500/1-12	2.575	0.149	2.724	2.634
	2cs500/1-12	2.198	0.140	2.338	
	3cs500/1-12	2.693	0.146	2.839	
	1ce500/1-12	2.520	0.148	2.668	2.546
	2ce500/1-12	2.512	0.121	2.633	
	3ce500/1-12	2.231	0.106	2.337	

**Table C-13** %Oil removal on the cotton fabric after washing by using a mixed surfactant of 0.1wt% Alfoterra 145-3PO and 5wt% Tergitol 15S5 (0.3 %w/v active surfactant) with STPP builder at 5%w/v NaCl concentrations under hardness 500 ppm and using iso-propanol as solvent

Hardness (ppm)	Hardness : STPP Ratio	Fabric	[Residue Oil] / Solution 50 ml (%w/v)			Oil Removal / 50 ml (%w/v)	% Oil Removal	% Oil Removal Avg.
			No.1	No.2	Total			
500	01:00.5	cs500/1	0.713	0.125	0.838	1.796	68.173	67.198
		cs500/2	0.762	0.126	0.888	1.746	66.274	
		cs500/3	0.741	0.124	0.865	1.769	67.148	
	1:01	cs500/4	0.702	0.102	0.804	1.830	69.463	68.843
		cs500/5	0.714	0.103	0.817	1.817	68.970	
		cs500/6	0.718	0.122	0.840	1.794	68.097	
	1:05	cs500/7	0.887	0.118	1.005	1.629	61.832	62.149
		cs500/8	0.879	0.123	1.002	1.632	61.946	
		cs500/9	0.872	0.111	0.983	1.651	62.668	
	1:20	cs500/10	0.910	0.107	1.017	1.617	61.377	61.339
		cs500/11	0.921	0.103	1.024	1.610	61.111	
		cs500/12	0.903	0.110	1.013	1.621	61.529	

**Table C-14** %Oil removal on the cotton fabric after washing by using a mixed surfactant of 0.1wt% Alfoterra 145-3PO and 5wt% Tergitol 15S5 (0.3 %w/v active surfactant) with EDTA builder at 5%w/v NaCl concentrations under hardness 500 ppm and using iso-propanol as solvent

Hardness (ppm)	Hardness : EDTA Ratio	Fabric	[Residue Oil] / Solution 50 ml (%w/v)			Oil Removal / 50 ml (%w/v)	% Oil Removal	% Oil Removal Avg.
			No.1	No.2	Total			
500	01:00.5	ce500/1	0.921	0.125	1.046	1.500	58.916	60.160
		ce500/2	0.874	0.128	1.002	1.544	60.644	
		ce500/3	0.882	0.113	0.995	1.551	60.919	
	1:01	ce500/4	0.826	0.113	0.939	1.607	63.119	63.027
		ce500/5	0.824	0.125	0.949	1.597	62.726	
		ce500/6	0.832	0.104	0.936	1.610	63.236	
	1:05	ce500/7	0.877	0.123	1.000	1.546	60.723	61.273
		ce500/8	0.845	0.147	0.992	1.554	61.037	
		ce500/9	0.852	0.114	0.966	1.580	62.058	
	1:20	ce500/10	0.968	0.100	1.068	1.478	58.052	57.777
		ce500/11	0.971	0.118	1.089	1.457	57.227	
		ce500/12	0.962	0.106	1.068	1.478	58.052	

**Table C-15** Initial oily soil concentration (%w/v) on the cotton fabric extracted by iso-propanol 50 ml/time

Type of Fabric	Fabric	[Initial Oily Soil] / Solution 50 ml (%w/v)			[Initial Soil] Avg. / 50 ml (%w/v)
		No.1	No.2	Total	
Cotton	1cs0/1-12	2.548	0.134	2.682	2.629
	2cs0/1-12	2.416	0.130	2.546	
	3cs0/1-12	2.531	0.128	2.659	
	1ce0/1-12	2.491	0.115	2.606	2.617
	2ce0/1-12	2.512	0.119	2.631	
	3ce0/1-12	2.501	0.112	2.613	

**Table C-16** %Oil removal on the cotton fabric after washing by using a mixed surfactant of 0.1wt% Alfoterra 145-3PO and 5wt% Tergitol 15S5 (0.3 %w/v active surfactant) with STPP builder at 5%w/v NaCl concentrations under hardness 0 ppm and using iso-propanol as solvent

Hardness (ppm)	Hardness : STPP Ratio	Fabric	[Residue Oil] / Solution 50 ml (%w/v)			Oil Removal / 50 ml (%w/v)	% Oil Removal	% Oil Removal Avg.
			No.1	No.2	Total			
0	01:00.5	cs0/1	0.324	0.132	0.456	2.173	82.655	82.807
		cs0/2	0.321	0.138	0.459	2.170	82.541	
		cs0/3	0.307	0.134	0.441	2.188	83.226	
	1:01	cs0/4	0.283	0.136	0.419	2.210	84.062	83.986
		cs0/5	0.291	0.142	0.433	2.196	83.530	
		cs0/6	0.280	0.131	0.411	2.218	84.367	
	1:05	cs0/7	0.401	0.138	0.539	2.090	79.498	80.005
		cs0/8	0.398	0.147	0.545	2.084	79.270	
		cs0/9	0.358	0.135	0.493	2.136	81.248	
	1:20	cs0/10	0.467	0.124	0.591	2.038	77.520	77.000
		cs0/11	0.501	0.134	0.635	1.994	75.846	
		cs0/12	0.459	0.129	0.588	2.041	77.634	

**Table C-17** %Oil removal on the cotton fabric after washing by using a mixed surfactant system at 0.3 %w/v active surfactant and 5%w/v NaCl concentrations with EDTA builder under hardness 0 ppm and using iso-propanol as solvent

Hardness (ppm)	Hardness : EDTA Ratio	Fabric	[Residue Oil] / Solution 50 ml (%w/v)			Oil Removal / 50 ml (%w/v)	% Oil Removal	% Oil Removal Avg.
			No.1	No.2	Total			
0	01:00.5	ce0/1	0.346	0.142	0.488	2.129	81.353	80.296
		ce0/2	0.382	0.147	0.529	2.088	79.786	
		ce0/3	0.372	0.158	0.530	2.087	79.748	
	1:01	ce0/4	0.326	0.134	0.460	2.157	82.423	83.174
		ce0/5	0.292	0.145	0.437	2.180	83.301	
		ce0/6	0.287	0.137	0.424	2.193	83.798	
	1:05	ce0/7	0.347	0.138	0.485	2.132	81.467	82.002
		ce0/8	0.353	0.135	0.488	2.129	81.353	
		ce0/9	0.309	0.131	0.440	2.177	83.187	
	1:20	ce0/10	0.376	0.124	0.500	2.117	80.894	81.009
		ce0/11	0.362	0.131	0.493	2.124	81.162	
		ce0/12	0.384	0.114	0.498	2.119	80.971	

**Table C-18** Initial oily soil concentration (%w/v) on the polyester/cotton (65/35) blend fabric extracted by iso-propanol 50 ml/time

Type of Fabric	Fabric	[Initial Oily Soil] / Solution 50 ml (%w/v)			[Initial Soil] Avg. / 50 ml (%w/v)
		No.1	No.2	Total	
Blend	1bs500/1-12	2.003	0.116	2.119	2.102
	2bs500/1-12	1.981	0.105	2.086	
	3bs500/1-12	1.989	0.113	2.102	
	1be500/1-12	2.134	0.095	2.229	2.224
	2be500/1-12	2.062	0.099	2.161	
	3be500/1-12	2.168	0.113	2.281	

**Table C-17** %Oil removal on the polyester/cotton (65/35) blend fabric after washing by using a mixed surfactant of 0.1wt% Alfoterra 145-3PO and 5wt% Tergitol 15S5 (0.3 %w/v active surfactant) with STPP builder at different NaCl concentrations under hardness 500 ppm and using iso-propanol as solvent

Hardness (ppm)	Hardness : STPP Ratio	Fabric	[Residue Oil] / Solution 50 ml (%w/v)			Oil Removal / 50 ml (%w/v)	% Oil Removal	% Oil Removal Avg.
			No.1	No.2	Total			
500	01:00.5	bs500/1	0.568	0.132	0.700	1.402	66.698	67.000
		bs500/2	0.557	0.128	0.685	1.417	67.412	
		bs500/3	0.562	0.134	0.696	1.406	66.889	
	1:01	bs500/4	0.598	0.120	0.718	1.384	65.842	65.002
		bs500/5	0.621	0.101	0.722	1.380	65.652	
		bs500/6	0.642	0.125	0.767	1.335	63.511	
	1:05	bs500/7	0.692	0.120	0.812	1.290	61.370	62.004
		bs500/8	0.681	0.128	0.809	1.293	61.513	
		bs500/9	0.644	0.131	0.775	1.327	63.130	
	1:20	bs500/10	0.688	0.129	0.817	1.285	61.132	61.005
		bs500/11	0.704	0.135	0.839	1.263	60.086	
		bs500/12	0.695	0.108	0.803	1.299	61.798	



**Table C-18** %Oil removal on the polyester/cotton (65/35) blend fabric after washing by using a mixed surfactant of 0.1wt% Alfoterra 145-3PO and 5wt% Tergitol 15S5 (0.3 %w/v active surfactant) with EDTA builder at different NaCl concentrations under hardness 500 ppm and using iso-propanol as solvent

Hardness (ppm)	Hardness : EDTA Ratio	Fabric	[Residue Oil] / Solution 50 ml (%w/v)			Oil Removal / 50 ml (%w/v)	% Oil Removal	% Oil Removal Avg.
			No.1	No.2	Total			
500	01:00.5	be500/1	0.767	0.134	0.901	1.323	59.487	60.012
		be500/2	0.739	0.138	0.877	1.347	60.567	
		be500/3	0.755	0.135	0.890	1.334	59.982	
	1:01	be500/4	0.747	0.111	0.858	1.366	61.421	62.005
		be500/5	0.739	0.113	0.852	1.372	61.691	
		be500/6	0.725	0.100	0.825	1.399	62.905	
	1:05	be500/7	0.748	0.122	0.870	1.354	60.881	61.001
		be500/8	0.741	0.147	0.888	1.336	60.072	
		be500/9	0.730	0.114	0.844	1.380	62.050	
	1:20	be500/10	0.813	0.135	0.948	1.276	57.374	57.014
		be500/11	0.828	0.137	0.965	1.259	56.610	
		be500/12	0.821	0.134	0.955	1.269	57.059	

**Table C-19** Initial oily soil concentration (%w/v) on the polyester/cotton (65/35) blend fabric extracted by iso-propanol 50 ml/time

Type of Fabric	Fabric	[Initial Oily Soil] / Solution 50 ml (%w/v)			[Initial Soil] Avg. / 50 ml (%w/v)
		No.1	No.2	Total	
Blend	1bs0/1-12	1.988	0.119	2.107	2.188
	2bs0/1-12	2.107	0.095	2.202	
	3bs0/1-12	2.154	0.101	2.255	
	1be0/1-12	2.087	0.119	2.206	2.139
	2be0/1-12	1.992	0.095	2.087	
	3be0/1-12	2.024	0.101	2.125	

**Table C-20** %Oil removal on the polyester/cotton (65/35) blend fabric after washing by using a mixed surfactant of 0.1wt% Alfoterra 145-3PO and 5wt% Tergitol 15S5 (0.3 %w/v active surfactant) with STPP builder at different NaCl concentrations under hardness 0 ppm and using iso-propanol as solvent

Hardness (ppm)	Hardness : STPP Ratio	Fabric	[Residue Oil] / Solution 50 ml (%w/v)			Oil Removal / 50 ml (%w/v)	% Oil Removal	% Oil Removal Avg.
			No.1	No.2	Total			
0	01:00.5	bs0/1	0.339	0.028	0.367	1.821	83.227	83.013
		bs0/2	0.343	0.031	0.374	1.814	82.907	
		bs0/3	0.341	0.033	0.374	1.814	82.907	
	1:01	bs0/4	0.339	0.023	0.362	1.826	83.455	83.501
		bs0/5	0.337	0.027	0.364	1.824	83.364	
		bs0/6	0.342	0.015	0.357	1.831	83.684	
	1:05	bs0/7	0.445	0.021	0.466	1.722	78.702	79.007
		bs0/8	0.452	0.022	0.474	1.714	78.336	
		bs0/9	0.413	0.025	0.438	1.750	79.982	
	1:20	bs0/10	0.499	0.046	0.545	1.643	75.091	76.005
		bs0/11	0.481	0.037	0.518	1.670	76.325	
		bs0/12	0.467	0.045	0.512	1.676	76.600	

**Table C-21** %Oil removal on the polyester/cotton (65/35) blend fabric after washing by using a mixed surfactant system at 0.3 %w/v active surfactant and 5%w/v NaCl concentrations with EDTA builder under hardness 0 ppm

Hardness (ppm)	Hardness : EDTA Ratio	Fabric	[Residue Oil] / Solution 50 ml (%w/v)			Oil Removal / 50 ml (%w/v)	% Oil Removal	% Oil Removal Avg.
			No.1	No.2	Total			
0	01:00.5	be0/1	0.331	0.025	0.356	1.783	83.357	83.014
		be0/2	0.343	0.030	0.373	1.766	82.562	
		be0/3	0.340	0.021	0.361	1.778	83.123	
	1:01	be0/4	0.323	0.034	0.357	1.782	83.310	84.011
		be0/5	0.304	0.030	0.334	1.805	84.385	
		be0/6	0.297	0.038	0.335	1.804	84.338	
	1:05	be0/7	0.361	0.034	0.395	1.744	81.533	82.001
		be0/8	0.346	0.037	0.383	1.756	82.094	
		be0/9	0.345	0.032	0.377	1.762	82.375	
	1:20	be0/10	0.408	0.035	0.443	1.696	79.289	80.006
		be0/11	0.396	0.024	0.420	1.719	80.365	
		be0/12	0.391	0.029	0.420	1.719	80.365	

**Table C-22** Initial oily soil concentration (%w/v) on the polyester fabric extracted by iso-propanol 50 ml/time

Type of Fabric	Fabric	[Initial Oily Soil] / Solution 50 ml (%w/v)			[Initial Soil] Avg. / 50 ml (%w/v)
		No.1	No.2	Total	
Polyester	1ps500/1-12	1.591	0.108	1.699	1.649
	2ps500/1-12	1.529	0.081	1.610	
	3ps500/1-12	1.552	0.085	1.637	
	1pe500/1-12	1.659	0.058	1.717	1.681
	2pe500/1-12	1.573	0.041	1.614	
	3pe500/1-12	1.648	0.063	1.711	

**Table C-23** %Oil removal on the polyester fabric after washing by using a mixed surfactant of 0.1wt% Alfoterra 145-3PO and 5wt% Tergitol 15S5 (0.3 %w/v active surfactant) with STPP builder at different NaCl concentrations under hardness 500 ppm and using iso-propanol as solvent

Hardness (ppm)	Hardness : STPP Ratio	Fabric	[Residue Oil] / Solution 50 ml (%w/v)			Oil Removal / 50 ml (%w/v)	% Oil Removal	% Oil Removal Avg.
			No.1	No.2	Total			
500	01:00.5	ps500/1	0.482	0.104	0.586	1.063	64.463	63.008
		ps500/2	0.503	0.103	0.606	1.043	63.250	
		ps500/3	0.527	0.111	0.638	1.011	61.310	
	1:01	ps500/4	0.514	0.108	0.622	1.027	62.280	62.017
		ps500/5	0.519	0.104	0.623	1.026	62.220	
		ps500/6	0.524	0.110	0.634	1.015	61.552	
	1:05	ps500/7	0.554	0.110	0.664	0.985	59.733	61.007
		ps500/8	0.520	0.103	0.623	1.026	62.220	
		ps500/9	0.529	0.113	0.642	1.007	61.067	
	1:20	ps500/10	0.554	0.110	0.664	0.985	59.733	60.016
		ps500/11	0.547	0.103	0.650	0.999	60.582	
		ps500/12	0.551	0.113	0.664	0.985	59.733	

**Table C-24** %Oil removal on the polyester fabric after washing by using a mixed surfactant of 0.1wt% Alfoterra 145-3PO and 5wt% Tergitol 15S5 (0.3 %w/v active surfactant) with EDTA builder at different NaCl concentrations under hardness 500 ppm and using iso-propanol as solvent

Hardness (ppm)	Hardness : EDTA Ratio	Fabric	[Residue Oil] / Solution 50 ml (%w/v)			Oil Removal / 50 ml (%w/v)	% Oil Removal	% Oil Removal Avg.
			No.1	No.2	Total			
500	01:00.5	pe500/1	0.574	0.108	0.682	0.999	59.429	59.012
		pe500/2	0.573	0.116	0.689	0.992	59.012	
		pe500/3	0.586	0.110	0.696	0.985	58.596	
	1:01	pe500/4	0.561	0.112	0.673	1.008	59.964	60.004
		pe500/5	0.567	0.101	0.668	1.013	60.262	
		pe500/6	0.569	0.107	0.676	1.005	59.786	
	1:05	pe500/7	0.568	0.111	0.679	1.002	59.607	60.004
		pe500/8	0.564	0.103	0.667	1.014	60.321	
		pe500/9	0.565	0.106	0.671	1.010	60.083	
	1:20	pe500/10	0.641	0.102	0.743	0.938	55.800	56.018
		pe500/11	0.627	0.105	0.732	0.949	56.454	
		pe500/12	0.636	0.107	0.743	0.938	55.800	

**Table C-25** Initial oily soil concentration (%w/v) on the polyester fabric extracted by iso-propanol 50 ml/time

Type of Fabric	Fabric	[Initial Oily Soil] / Solution 50 ml (%w/v)			[Initial Soil] Avg. / 50 ml (%w/v)
		No.1	No.2	Total	
Polyester	1ps0/1-12	1.600	0.075	1.675	1.676
	2ps0/1-12	1.575	0.096	1.671	
	3ps0/1-12	1.587	0.096	1.683	
	1pe0/1-12	1.592	0.074	1.666	1.665
	2pe0/1-12	1.594	0.088	1.682	
	3pe0/1-12	1.586	0.061	1.647	

**Table C-26** %Oil removal on the polyester fabric after washing by using a mixed surfactant of 0.1wt% Alfoterra 145-3PO and 5wt% Tergitol 15S5 (0.3 %w/v active surfactant) with STPP builder at different NaCl concentrations under hardness 0 ppm and using iso-propanol as solvent

Hardness (ppm)	Hardness : STPP Ratio	Fabric	[Residue Oil] / Solution 50 ml (%w/v)			Oil Removal / 50 ml (%w/v)	% Oil Removal	% Oil Removal Avg.
			No.1	No.2	Total			
0	01:00.5	ps0/1	0.261	0.015	0.276	1.400	83.532	82.518
		ps0/2	0.253	0.022	0.275	1.401	83.592	
		ps0/3	0.308	0.020	0.328	1.348	80.430	
	1:01	ps0/4	0.251	0.009	0.260	1.416	84.487	82.737
		ps0/5	0.283	0.016	0.299	1.377	82.160	
		ps0/6	0.295	0.014	0.309	1.367	81.563	
	1:05	ps0/7	0.349	0.019	0.368	1.308	78.043	78.003
		ps0/8	0.356	0.020	0.376	1.300	77.566	
		ps0/9	0.348	0.014	0.362	1.314	78.401	
	1:20	ps0/10	0.382	0.018	0.400	1.276	76.134	76.014
		ps0/11	0.381	0.023	0.404	1.272	75.895	
		ps0/12	0.383	0.019	0.402	1.274	76.014	

**Table C-27** %Oil removal on the polyester fabric after washing by using a mixed surfactant system at 0.3 %w/v active surfactant and 5%w/v NaCl concentrations with EDTA builder under hardness 0 ppm and using iso-propanol as solvent

Hardness (ppm)	Hardness : EDTA Ratio	Fabric	[Residue Oil] / Solution 50 ml (%w/v)			Oil Removal / 50 ml (%w/v)	% Oil Removal	% Oil Removal Avg.
			No.1	No.2	Total			
0	01:00.5	pe0/1	0.353	0.021	0.374	1.291	77.538	77.257
		pe0/2	0.356	0.023	0.379	1.286	77.237	
		pe0/3	0.358	0.025	0.383	1.282	76.997	
	1:01	pe0/4	0.256	0.015	0.271	1.394	83.724	81.922
		pe0/5	0.261	0.013	0.274	1.391	83.544	
		pe0/6	0.342	0.016	0.358	1.307	78.498	
	1:05	pe0/7	0.309	0.015	0.324	1.341	80.541	80.000
		pe0/8	0.313	0.023	0.336	1.329	79.820	
		pe0/9	0.320	0.019	0.339	1.326	79.640	
	1:20	pe0/10	0.339	0.009	0.348	1.317	79.099	79.019
		pe0/11	0.337	0.011	0.348	1.317	79.099	
		pe0/12	0.340	0.012	0.352	1.313	78.859	

## 3.3 %Oil Removal in Each Step

**Table C-28** Initial oily soil concentration (%w/v) on the cotton fabric extracted by dichloromethane 50 ml/time

Type of Fabric	Fabric	[Initial Oily Soil] / Solution 50 ml (%w/v)			[Soil] Avg./50 ml (%w/v)	[Soil] Avg./100 ml (%w/v)
		No.1	No.2	Total		
Cotton	1C1-12	2.368	0.146	2.514	2.530	1.265
	2C1-12	2.443	0.133	2.576		
	3C1-12	2.367	0.133	2.500		
	1C13-24	2.419	0.161	2.580	2.571	1.286
	2C13-24	2.418	0.152	2.570		
	3C13-24	2.382	0.182	2.564		
	1C25-36	2.439	0.212	2.651	2.605	1.303
	2C25-36	2.419	0.200	2.619		
	3C25-36	2.376	0.170	2.546		
	1C37-48	2.432	0.160	2.592	2.606	1.303
	2C37-48	2.461	0.181	2.642		
	3C37-48	2.415	0.170	2.585		

**Table C-29** %Oil removal in each step of cotton fabric at 0.3 %w/v active surfactant and NaCl 5%w/v with using dichloromethane as solvent

Hardness (ppm)	No.	[Oil Removal] (%w/v)			[Initial Soil] / 100 ml (%w/v)	%Oil removal in each step (%w/v)	%Total Oil Removal, extraction oil in solution
		UV / Solution 1000 ml	Solution 100 ml	Total / 100 ml			
0	W/C1-12	0.011	0.110	1.040	1.265	8.696	82.213
	R1/C1-12	0.075	0.750			59.289	
	R2/C1-12	0.018	0.180			14.229	
100	W/C13-24	0.016	0.160	0.650	1.286	12.445	50.557
	R1/C13-24	0.036	0.360			28.001	
	R2/C13-24	0.013	0.130			10.111	
500	W/C25-36	0.022	0.220	0.610	1.303	16.888	46.827
	R1/C25-36	0.030	0.300			23.030	
	R2/C25-36	0.009	0.090			6.909	
1000	W/C37-48	0.023	0.230	0.520	1.303	17.649	39.903
	R1/C37-48	0.026	0.260			19.951	
	R2/C37-48	0.003	0.030			2.302	

### Appendix D Experimental Data of Titration to Reach Residual Anionic Surfactant (Alfoterra 145-3PO)

**Table D-1** Residual Alfoterra ( $\mu\text{M}$ ) in a mixed surfactant system of 0.1wt% Alfoterra 145-3PO and 5wt% Tergitol 15S5 (3%w/v active surfactant) at 5%w/v NaCl under the presence and absence of hardness (without fabric)

Hardness (ppm)	Initial Alfoterra Conc.	1			2			3			4			5			Residual Avg. ( $\mu\text{M}$ )	STD-EV ( $\mu\text{m}$ )	Effect of Hardness ( $\mu\text{M}$ )
		Hya-mine	Residual Alfoterra		Hya-mine	Residual Alfoterra		Hya-mine	Residual Alfoterra		Hya-mine	Residual Alfoterra		Hya-mine	Residual Alfoterra				
			$\mu\text{l}$	$\mu\text{l}$		$\mu\text{M}$	$\mu\text{l}$		$\mu\text{l}$	$\mu\text{M}$		$\mu\text{l}$	$\mu\text{l}$		$\mu\text{M}$	$\mu\text{l}$			
0	121.7391	29	1200	120.8333	25	1000	125.0000	19	800	118.7500	29	1200	120.8333	29	1200	120.8333	121.2500	2.28	0.4891
100	121.7391	16	800	100.0000	17	800	106.2500	25	1000	110.0000	17	800	106.2500	16	800	100.0000	104.5000	4.38	17.2391
500	121.7391	12	800	75.0000	13	800	81.2500	20	1000	90.0000	12	800	75.0000	13	800	81.2500	80.5000	6.16	41.2391
1000	121.7391	15	1000	75.0000	14	1000	70.0000	16	1000	80.0000	15	1000	75.0000	14	1000	70.0000	74.0000	4.18	47.7391

**Table D-2** Residual Alfoterra ( $\mu\text{M}$ ) after washing and rinsing of soiled cotton fabric by using a mixed surfactant system of 0.1wt% Alfoterra 145-3PO and 5wt% Tergitol 15S5 (3%w/v active surfactant) at 5%w/v NaCl under the presence and absence of hardness

Hardness (ppm)/ Step	Initial Conc. $\mu\text{M}$	1		2		3		4		5		Residual Avg. ( $\mu\text{M}$ )	Precipitated Surf. ( $\mu\text{M}$ )	Ad-sorp. Surf. ( $\mu\text{M}$ )	De-sorp. Surf. $R_1+R_2$	Lost Surf. ( $\mu\text{M}$ )					
		Residual Alfoterra		Residual Alfoterra		Residual Alfoterra		Residual Alfoterra		Residual Alfoterra											
		$\mu\text{l}$	$\mu\text{M}$	$\mu\text{l}$	$\mu\text{M}$	$\mu\text{l}$	$\mu\text{M}$	$\mu\text{l}$	$\mu\text{M}$	$\mu\text{l}$	$\mu\text{M}$						$\mu\text{l}$	$\mu\text{M}$			
0/W	121.74	8.0	1400	28.57	11.5	1400	41.07	6.0	1039	28.87	7.0	1039	33.69	8.0	1300	30.77	32.59	0.49	88.66	25.29	63.37
100/W	121.74	11.5	1600	35.94	11.0	1600	34.38	11.0	1600	34.38	11.5	1600	35.94	9.0	1400	32.14	34.55	17.24	69.95	16.90	53.04
500/W	121.74	14.0	1600	43.75	15.0	1600	46.88	8.0	1100	36.36	9.0	1100	40.91	11.0	1300	42.31	42.04	41.24	38.46	10.07	28.38
1000/W	121.74	11.0	1200	45.83	14.0	1400	50.00	11.0	1200	45.83	10.0	1000	50.00	14.0	1300	53.85	49.10	47.74	24.90	6.25	18.65
0/R1	0.00	6.5	1400	23.21	6.5	1400	23.21	5.0	1400	17.86	7.0	2000	17.50	4.5	1400	16.07	19.57				
100/R1	0.00	4.5	1800	12.50	6.0	1800	16.67	4.0	1600	12.50	6.0	2100	14.29	5.5	2100	13.10	13.81				
500/R1	0.00	4.0	3800	5.26	5.0	3800	6.58	4.0	2800	7.14	8.0	4600	8.70	5.5	2800	9.82	7.50				
1000/R1	0.00	4.0	3400	5.88	3.0	3400	4.41	2.0	3400	2.94	4.0	3400	5.88	2.0	3400	2.94	4.41				
0/R2	0.00	7.0	4800	7.29	8.0	4800	8.33	7.5	4800	7.81	6.5	4800	6.77	7.0	4800	7.29	7.50				
100/R2	0.00	4.0	8400	2.38	5.0	8400	2.98	6.0	8400	3.57	7.0	8400	4.17	4.0	8400	2.38	3.10				
500/R2	0.00	3.0	6800	2.21	4.0	6800	2.94	5.0	6800	3.68	3.0	6800	2.21	2.5	6800	1.84	2.57				
1000/R2	0.00	2.5	6800	1.84	3.0	6800	2.21	2.0	6800	1.47	2.5	6800	1.84	2.5	6800	1.84	1.84				



**Table D-3** Residual Alfoterra ( $\mu\text{M}$ ) after washing and rinsing of unsoiled cotton fabric by using a mixed surfactant system of 0.1wt% Alfoterra 145-3PO and 5wt% Tergitol 15S5 (3%w/v active surfactant) at 5%w/v NaCl under the absence of hardness (DI water)

Hardness (ppm)/ Step	Initial Alfoterra Conc. $\mu\text{M}$	1			2			3			Residual Avg. ( $\mu\text{M}$ )	STDEV ( $\mu\text{M}$ )	Delta ( $\mu\text{M}$ )	Precipitated Surf. ( $\mu\text{M}$ )	Adsorp. Surf. ( $\mu\text{M}$ )	Desorp. Surf. R1+R2 ( $\mu\text{M}$ )	Lost Surf. ( $\mu\text{M}$ )
		Hya-mine $\mu\text{l}$	Residual Alfoterra		Hya-mine $\mu\text{l}$	Residual Alfoterra		Hya-mine $\mu\text{l}$	Residual Alfoterra								
			$\mu\text{l}$	$\mu\text{M}$		$\mu\text{l}$	$\mu\text{M}$		$\mu\text{l}$	$\mu\text{M}$							
0/W	121.7391	8	800	50.0000	9	800	56.2500	11	900	61.1111	55.7870	5.5700	65.9521	0.4891	65.4630	28.0287	37.4343
0/R1	0.0000	12	2400	25.0000	11	2300	23.9130	13	2500	26.0000	24.9710	1.0438	24.9710				
0/R2	0.0000	6	10500	2.8571	6	9500	3.1579	6	9500	3.1579	3.0576	0.1736	3.0576				

### Appendix E Experimental Data of Critical Micelle Concentration

**Table E-1** Relationship between mixed surfactant concentration ( $\mu\text{M}$ ) and surface tension ( $\text{mN/m}$ ) by using a mixed surfactant system of 0.1wt% Alfoterra 145-3PO and 5wt% Tergitol 15-S-5 at 5%w/v NaCl with DI water

Mixed Surfactant Concentration		Surface Tension ( $\text{mN/m}$ )		
%w/v	$\mu\text{M}$	1	2	Avg.
0.0004	9.6119	34.70	34.30	34.50
0.0006	14.4179	34.10	33.70	33.90
0.0008	19.2239	32.70	32.30	32.50
0.0010	24.0299	32.60	32.20	32.40
0.0020	48.0597	31.00	30.40	30.70
0.0040	96.1195	30.80	30.30	30.55
0.0060	144.1792	30.10	29.80	29.95
0.0080	192.2389	30.20	29.70	29.95
0.0084	201.8509	30.00	29.40	29.70
0.0090	216.2688	29.80	29.60	29.70
0.0094	225.8807	29.80	29.30	29.55
0.0100	240.2987	29.70	29.40	29.55
0.0110	264.3285	29.70	29.60	29.65
0.0120	288.3584	29.70	29.70	29.70
0.0140	336.4181	29.70	29.60	29.65
0.0200	480.5973	29.70	29.40	29.55
0.0600	1441.7920	29.20	29.10	29.15

**Table E-2** Relationship between Alfoterra 145-3PO concentration ( $\mu\text{M}$ ) and surface tension (mN/m) at 5%w/v NaCl with DI water

Alfoterra Concentration		Surface Tension (mN/m)		
%w/v	$\mu\text{M}$	1	2	Avg.
0.0002	4.1408	51.30	51.80	51.55
0.0004	8.2816	43.10	43.70	43.40
0.0006	12.4224	40.20	39.50	39.85
0.0008	16.5631	38.80	40.10	39.45
0.0010	20.7039	37.30	36.00	36.65
0.0020	41.4079	33.60	33.30	33.45
0.0040	82.8157	32.70	32.10	32.40
0.0060	124.2236	32.70	32.50	32.60
0.0080	165.6315	33.30	33.00	33.15
0.0100	207.0393	33.10	33.00	33.05
0.0200	414.0787	33.80	33.80	33.80

**Table E-3** Relationship between Tergitol 15-S-5 concentration ( $\mu\text{M}$ ) and surface tension (mN/m) at 5%w/v NaCl with DI water

Tergitol Concentration		Surface Tension (mN/m)		
%w/v	$\mu\text{M}$	1	2	Avg.
0.0002	4.8193	51.70	50.10	50.90
0.0004	9.6386	44.40	44.50	44.45
0.0006	14.4578	42.30	42.30	42.30
0.0008	19.2771	38.80	37.80	38.30
0.0010	24.0964	36.70	36.40	36.55
0.0020	48.1928	31.40	31.40	31.40
0.0040	96.3855	29.80	30.10	29.95
0.0060	144.5783	29.70	29.60	29.65
0.0080	192.7711	29.70	29.60	29.65
0.0100	240.9639	29.70	29.60	29.65
0.0200	481.9277	29.50	29.50	29.50

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