Sustainability in commercial laundering processes

Module 3
Washing process

Chapter 1

Sinner`s Circle and it`s effect on washing performance

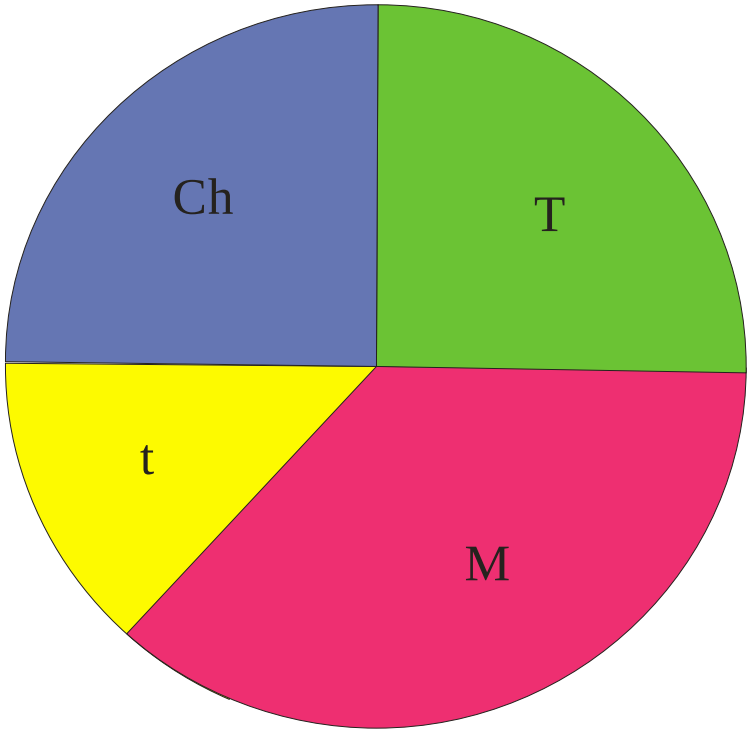
Content

- Sinner' Circle
- Mechanics and its effect on washing performance
- Chemistry and its effect on washing performance
- Temperature and its effect on washing performance
- Time and its effect on washing performance

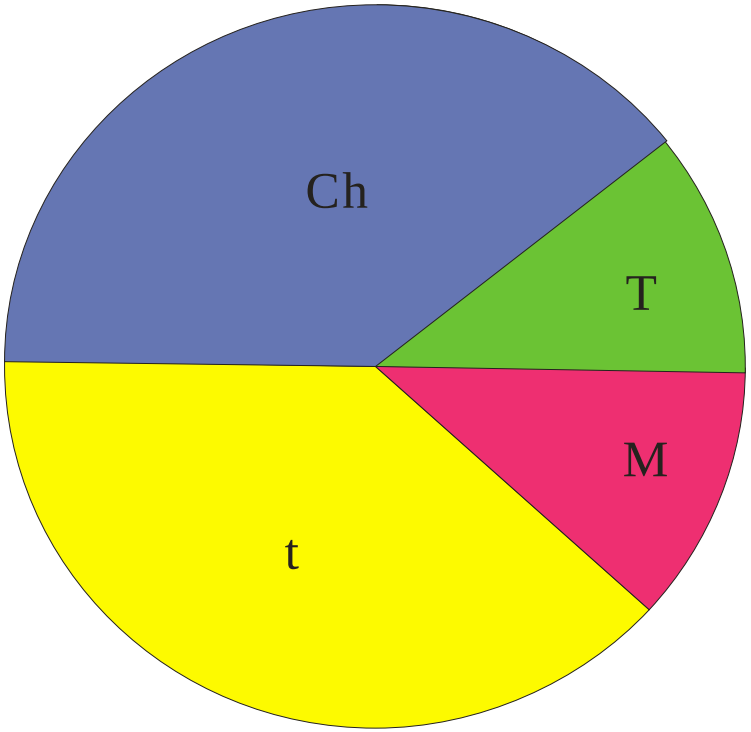
Purposes of Washing

- To remove local and general soiling
- To remove stains
- To maintain the whiteness of whitework and the brightness of colour of dyed and printed goods
- To keep or restore the original condition as far as physical characteristics like softness, fluffiness of pile, etc.
- To avoid chemical or physical damage which may unnecessarily shorten the life of the goods

Sinner's circle



t - time
T - temperature
M - mechanics
Ch - chemistry



Temperature -	*const.*	*Temperature* -	*low*
Chemical dosing -	*const.*	*Chemical dosing* -	*high*
Mechanics -	*high*	*Mechanics* -	*weak*
Time -	*shortened*	*Time* -	*prolonged*

Washer extractors

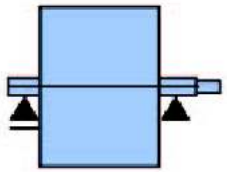
Basic elements of washer extractors are:

- **Outer case**, immovable liquor tank, fitted with a door through which machine can be loaded and unloaded
- **Perforated cylinder** (inner drum) which is mounted in a way as to rotate on a horizontal axis within an outer case which holds the wash liquor, it can be sectional or not depending on load capacity, equipped with lifting vanes
- **Reversing mechanism** which allows the cage to make several revolutions in one direction followed by the same number of revolutions in the opposite direction, to avoid the load becoming tangled and knotted
- **Electric drive, heating elements or steam coils, inlet and outlet valves (water, steam), control – steering system**.

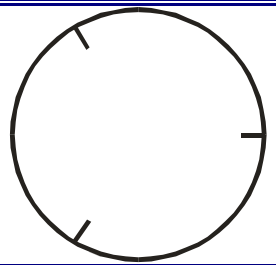
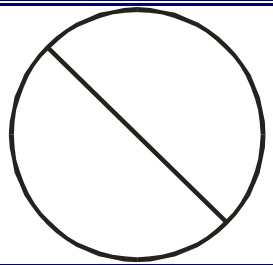
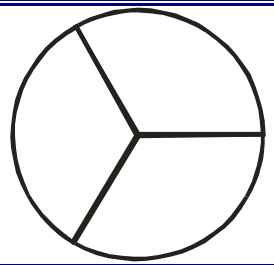
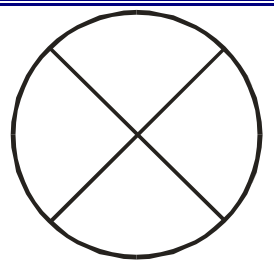
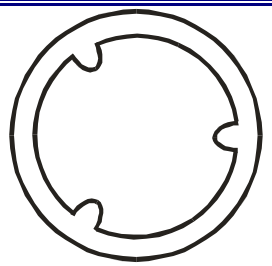
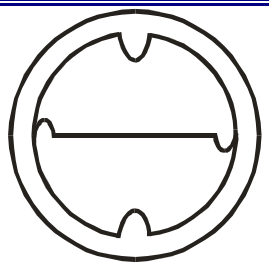
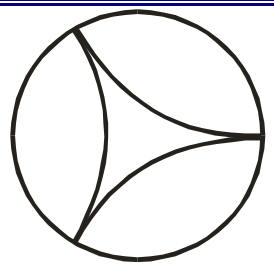
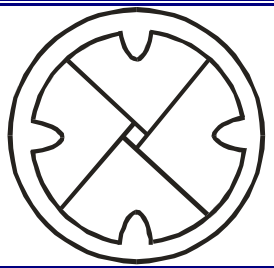
Washer extractor

Product Range
Barrier-Wall Type Favorit

Washer Extractor
Side Loader
Two-side
bearing design



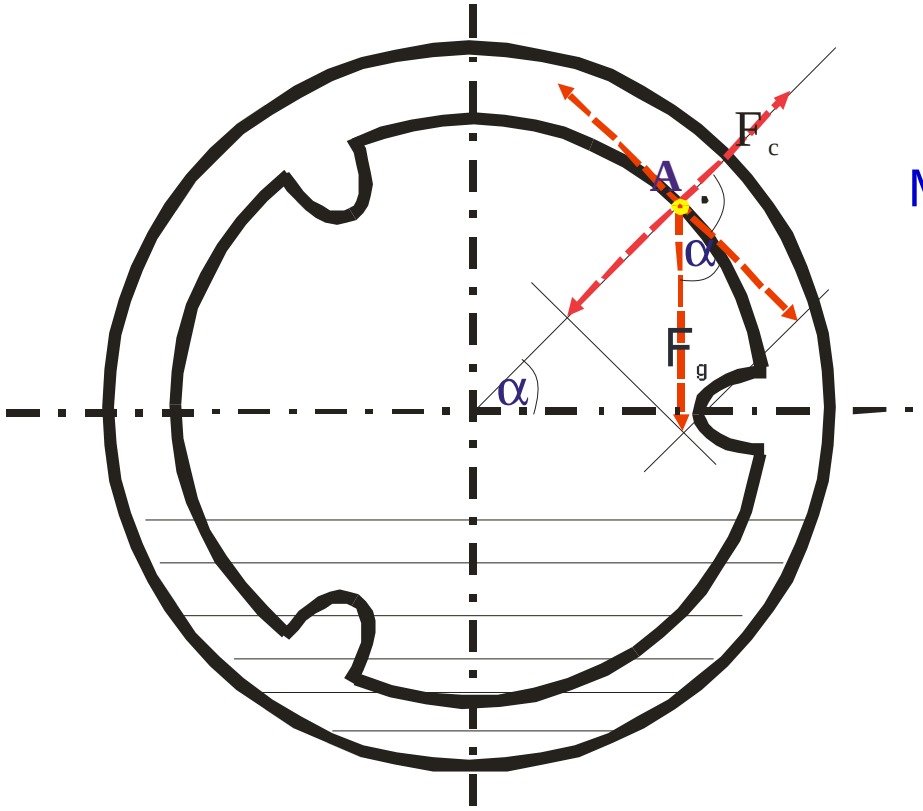
Construction of inner drums

Drum diameter [mm]			
900	900 - 1400	1400 - 1700	Above 1700
Marking			
O	D	Y	X
			
			

Mechanical factor and its effect on washing performance

- The movement of the wash in the washer extractor is caused by revolutions of inner drum
- Its intensity depends on peripheral speed of the drum, i.e. number of revolutions per minute
- Depending on peripheral speed the effect of mechanical action is diversified, from low to significant
- If the peripheral speed is a little lower from the speed equilibrating, the wash weight is falling down under the so called **falling angle, α**

Mechanical factor and its effect on washing performance



F_c - centrifugal force
F_g - gravity force

Mechanical factor (G) is defined as sinα

$$\sin\alpha = \frac{F_c}{F_g} = \frac{m\omega^2 r}{mg} = G$$

$$\sin\alpha = \frac{m\left(\frac{\pi n}{30}\right)^2 \frac{D}{2}}{mg} = 0.000555 D n^2 = G$$

where:
n – number of revolutions [rev./min]
D – diameter of drum [m]

Mechanical factor and its effect on washing performance

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The G values for washer extractors

Type	Load capacity [kg]	Drum diameter [mm]	Washing revolutions [1/min]	G
IPSO/HF 205	20.0	760	40	0.68
D'Hooge/Junior	21.0	700	41	0.66
Girbau/HS 3022	22.0	740	44	0.80
Wascator/220	22.0	750	44	0.81
Dubix/FAS 230	23.0	625	52	0.95
Primus/F 55	55.0	914	40	0.82
Luniwash/160	60.0	1120	27	0.46
Wascator/804	80.0	1120	36	0.81
D'Hooge/900	90.0	1220	32	0.70

Mechanical factor and its effect on washing performance

- In majority of washer extractors G factor in the range of 0.64-0.77 (for low and medium load capacity) and even 0.5 (for high load capacity) is considered
- It is caused by an application of such textile goods which require gentle action during the washing process and high mechanical action can damage or shorten the life of the goods
- The last developments in construction of washer extractors made possible to introduce a continuous regulation of the falling angles of 0.21-0.34. If needed, for the particular textile goods resistant for the mechanical action, the falling angle up to even 0.87 can be increased

Mechanical factor and its effect on washing performance

The mechanical action is also affected by:

- **load ratio** (the quotient of an inner drum volume in dm^3 to the wash mass) expressed in [dm^3/kg] or simply 12:1
- **liquor ratio** (water level in drum) in washing and rinsing processes defined as the quotient of total water volume in the washer extractor to the wash mass expressed in [dm^3/kg] or simply 5:1; at the low level of the washing bath due to an increased friction forces the mechanical action is also increased
- **construction of an inner drum**; in sectional drums a decreased mechanical action is observed; an increase in the drum diameter is also associated with an increased mechanical effect

Optimal load ratios for washer extractors determined on practical assessment

- hotel wash (I degree of soiling) – 10:1
- medium soiled wash (II degree of soiling) – 12:1
- heavy soiled wash (III degree of soiling) – 14:1
- curtains and delicate goods – 14:1
- polyester/cotton blends – 20:1
- currently most universal load ratio of 11:1 is applied (ISO 9398 Standard)

Suggested liquor ratios (dm^3/kg) in washing and rinsing processes according to K. Hasenclever and J. Naumann

Stage	Type of textiles	Work liquor ratio, [dm^3/kg]	Total liquor ratio, [dm^3/kg]
Washing	Cotton	4 – 5	ca 5
	Polyester/cotton	4 – 6	6 – 8
Rinsing	Cotton	6 – 8	ca 8
	Polyester/cotton	ca 8	8 – 10

Dewatering of wash after intermediate and end spinning

The measure of the removal of moisture from textile being washed and rinsed is the dewatering constant **G** defined as a quotient of the centrifugal acceleration of the washer extractor drum to gravitational acceleration, and expressed as follows:

$$G = \frac{\omega^2 \cdot r}{g} \qquad \text{or} \qquad G = 0{,}000555\, D \cdot n^2$$

where: ***G*** – dewatering constant, ω – angular speed = πn/30

r = *D/2*, *g* = 9,81 m/s^2, ***D*** – inner drum diameter [m]

n – number of spinning revolutions per minute [min^{-1}]

$$G = 5{,}6 \cdot \left(\frac{n}{1000}\right)^2 \cdot D$$

where: ***D*** – inner drum diameter [cm]

Dewatering constant values (G) in washer extractors of different load capacity

Type	Load capacity [kg]	Drum diameter [mm]	Spinning revolutions [min^{-1}]	Dewatering constant (G)
IPSO/HF 205	20.0	760	900	343
D'Hooge/Junior	21.0	700	1000	390
Girbau/HS 3022	22.0	740	950	380
Wascator/220	22.0	750	850	300
Dubix/FAS 230	23.0	625	926	300
Primus/F 55	55.0	914	830	350
Luniwash/60	60.0	1120	780	380
D'Hooge/900	90.0	1220	750	383

Influence of different types of textiles on the end humidity after dewatering

Type	Surface mass [g/m²]	End humidity [%]
Viscose fabric	180	54
Viscose knitted fabric	180	65
Cotton fabric	180	42
Cotton knitted fabric	180	48
Linen fabric	220	40
Wool knitted fabric	–	27
Polyamide fabric	100	13
Polyamide staple fibre	–	15

DREAM OF THE WASHERWOMAN

(R. Berneiser, K. Ueberschär, Lehrbuch der Textilreinigung, VEB Fachbuchverlag, Leipzig 1980)

Water consumption in laundry

Water consumption in washer-extractors at the considered load (kg) depends on:

- applied washing technology
- different kinds of textiles to be washed and their soiling degree cause the changes in water consumption
- the main factor affecting the consumption of water in the technological process considered is the liquor ratio in particular phases of the washing process
- the number of these phases requiring the filling of the washing machine with water

Chemistry and its effect on washing performance

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Machines	Technological operations			Total consumption
	Wash	Wash[1)]	Rinsing	
Traditional washers	8.5	–	24.5	30.0
Old generation washer-extractors	8.5	–	21.5	30.0
New generation washer-extractors (average):				26.0
a) Newborns wash (also overalls)[1)]	8.5	8.5	19.0	36.0
b) 3 fold rinsing[2)]	8.5	–	19.0	27.5
c) 3 fold rinsing	8.5	–	17.0	25.5
d) 2 fold rinsing	8.5	–	12.0	20.5
Tunnel washers	total consumption			8.0
Disinfectors	total consumption			10.0
Sterilizers	total consumption			5.0
Washing stands for trolleys	total consumption			ca. 2000 dm^3/h

Water consumption in laundries (dm^3/kg of load)

1) pre-wash (2 operations) in separate machine,
2) higher liquor ratio (PET/cotton blend)

(A. Milczyński, *Poradnik Pralniczy*, SPENTEX ed., Łódź 2002)

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Main ingredients of contemporary washing powders:

- **Surface active agents (soaps, anionic, non-ionic)**
- **Sequestering agents (TPPNa, Zeolith A, NTA, EDTA etc.)**
- **Builders (sodium carbonate, sodium metasilicate, sodium sulphate, sodium perborate etc.)**
- **Enzymes (proteinases, lipases, cellulases, oxido-reductases) TAED system**
- **Phosphonates**
- **Organic copolymers**
- **Foam stabilizers (alkyl amides)**
- **NaCMC (sodium salt of carboxymethyl cellulose)**
- **Fluorescent brightening agents (FBA)**
- **Fragrance**
- **Dyestuff (ultramarine)**

BLEACHING/DISINFECTING AGENTS

- chlorine - containing bleaching/disinfecting agents (sodium hypochlorite, chloramine, isocyanurates),
- oxygen - containing bleaching/disinfecting agents (hydrogen peroxide, sodium perborate, peracetic acid,

$$H_2O_2 + OH^- \leftrightarrows H_2O + HOO^-$$

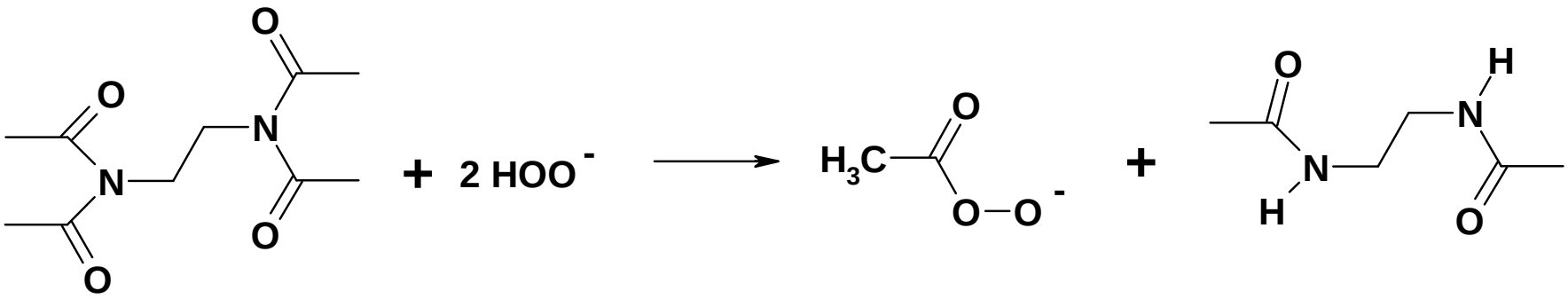
$$H_2O_2 + CH_3COOH \leftrightarrows H_2O + CH_3COOOH$$

- activated systems (TAED), modified activated systems (**H_2O_2 /TAED/ACL)**

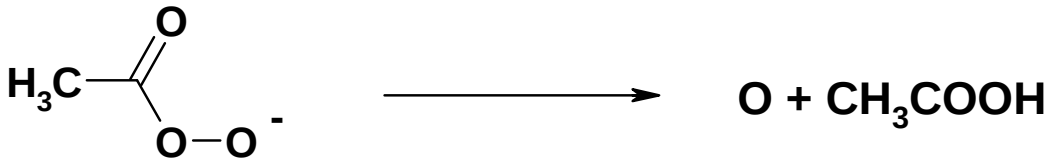
– for bleaching in tunnel batch washers (wfk)

Foellner, B., Bohnen, J., Kruessmann, H., Proceedings of the 40th wfk-International Detergency Conference, April 30th – May 3rd, (2001), Strasbourg, France, pp. 283-291

Chemistry and its effect on washing performance



TAED - *Tetra Acetyl Ethylene Diamine*
DAED - *Di Acetyl Ethylene Diamine*



Chemistry and its effect on washing performance

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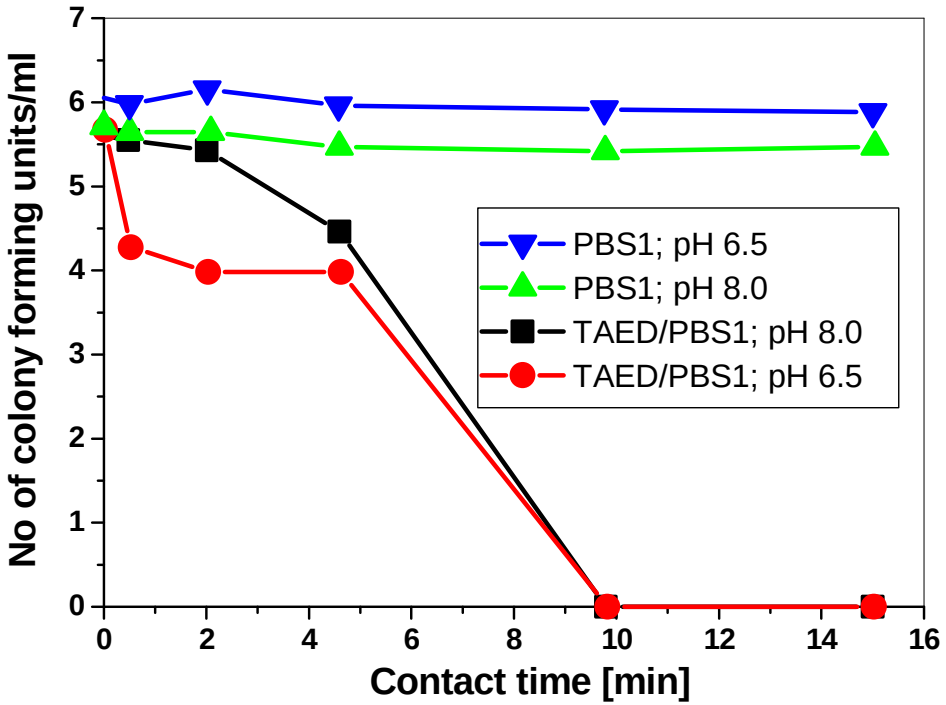
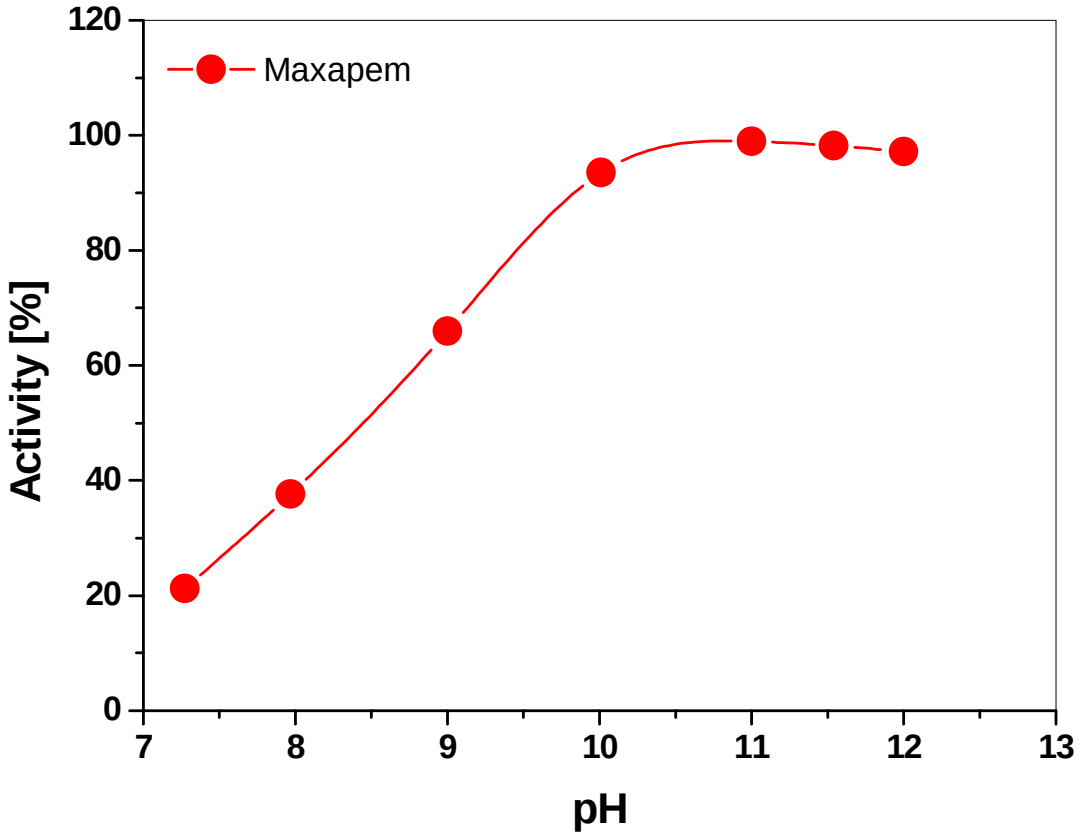
Bactericidal activity of TAED/PBS system towards *Legionella pneumophila**



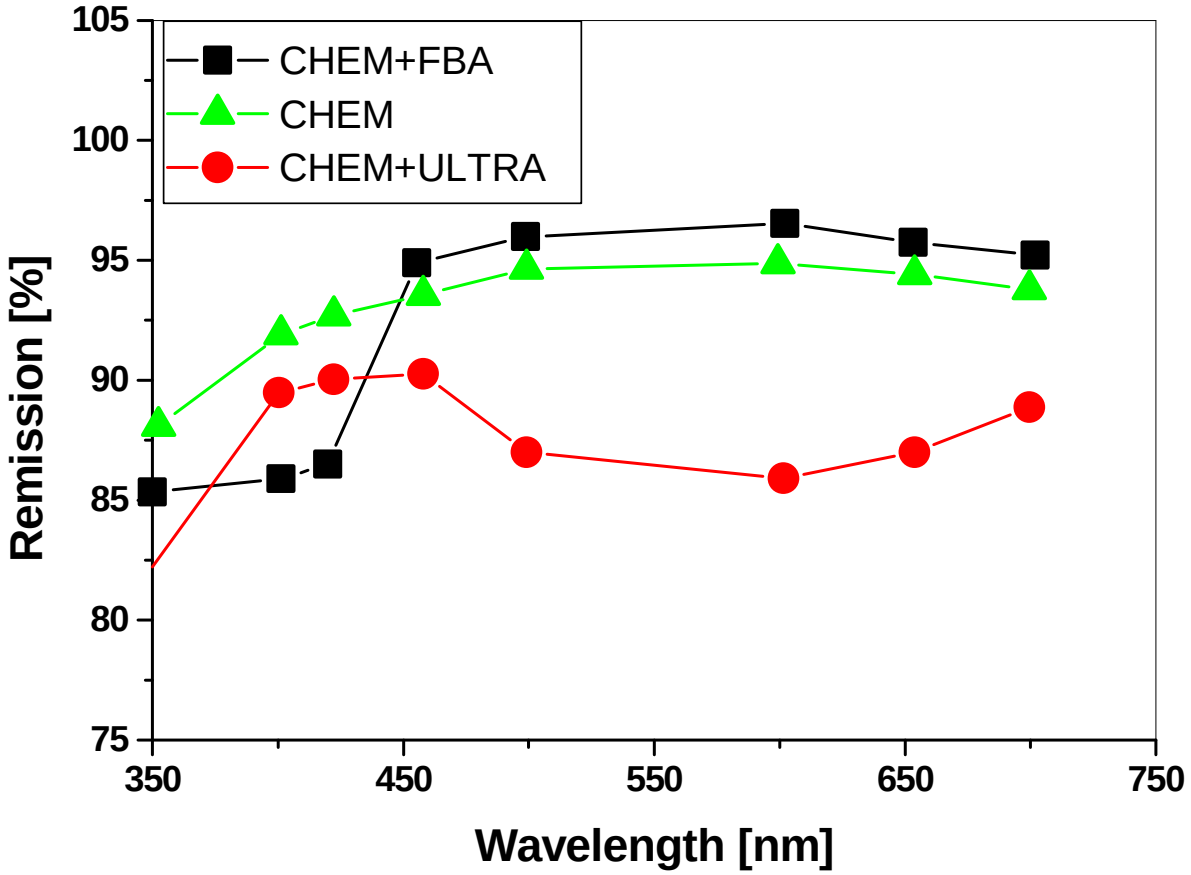
*George, I., *Proceedings of the 37th wfk-International Detergency Conference,* May 21-23, (1996), Krefeld, Germany, pp. 95-98

Chemistry and its effect on washing performance



The change of protease activity (MAXAPEM) vs pH of washing liquor

Chemistry and its effect on washing performance



Remission of cotton textile treated with various bleaching agents: chemical bleaching (chem), fluorescent brightening agent (FBA), ultramarine (ultra) vs wavelength of light

Chemistry and its effect on washing performance

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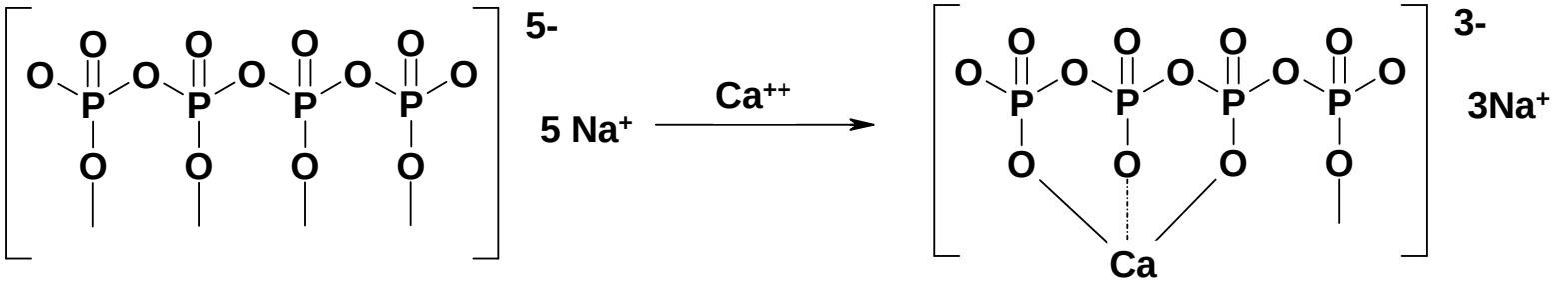
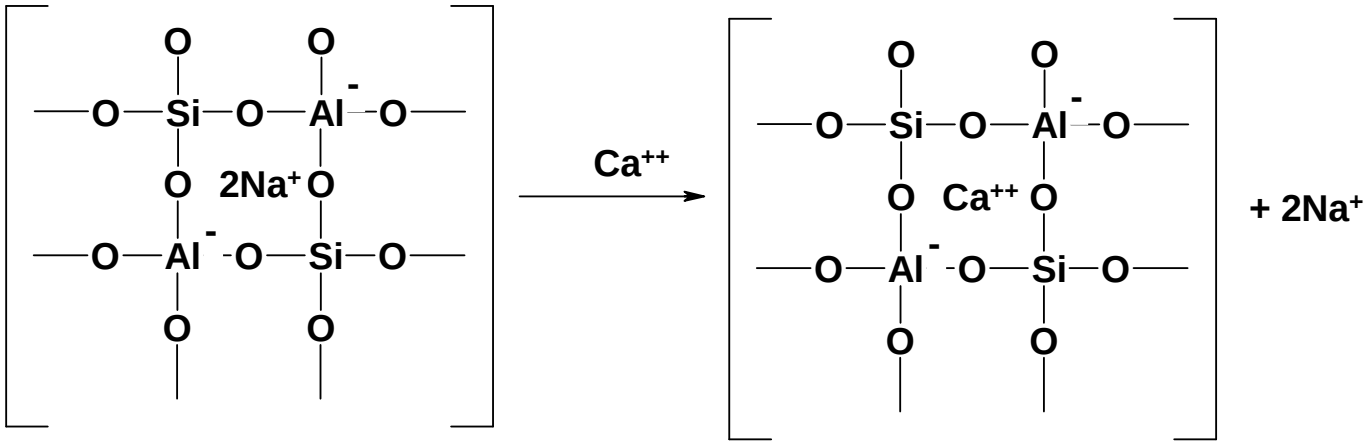
Sequestering agents (TPPNa - sodium tripolyphosphate and Zeolite)

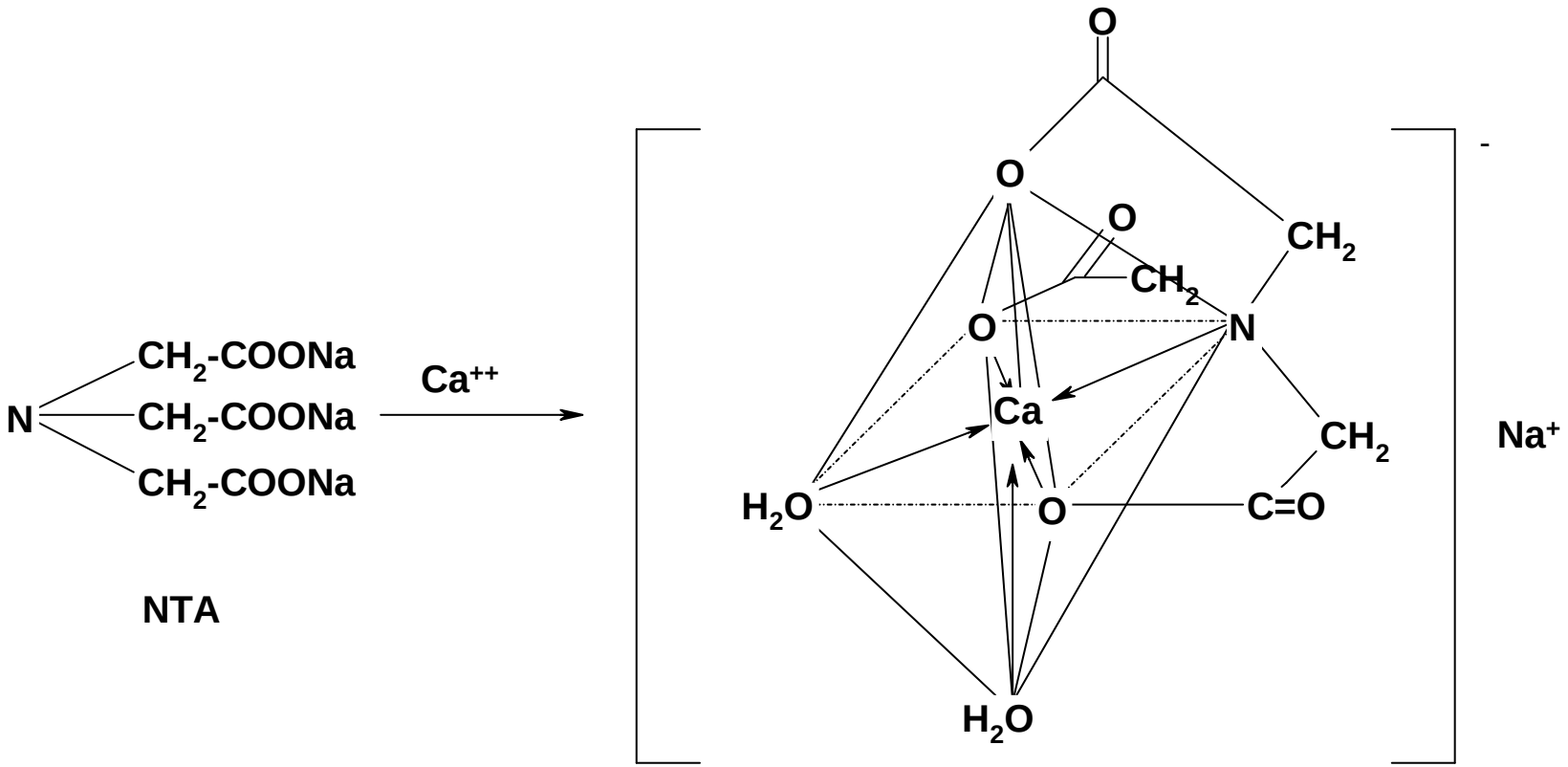


TPPNa

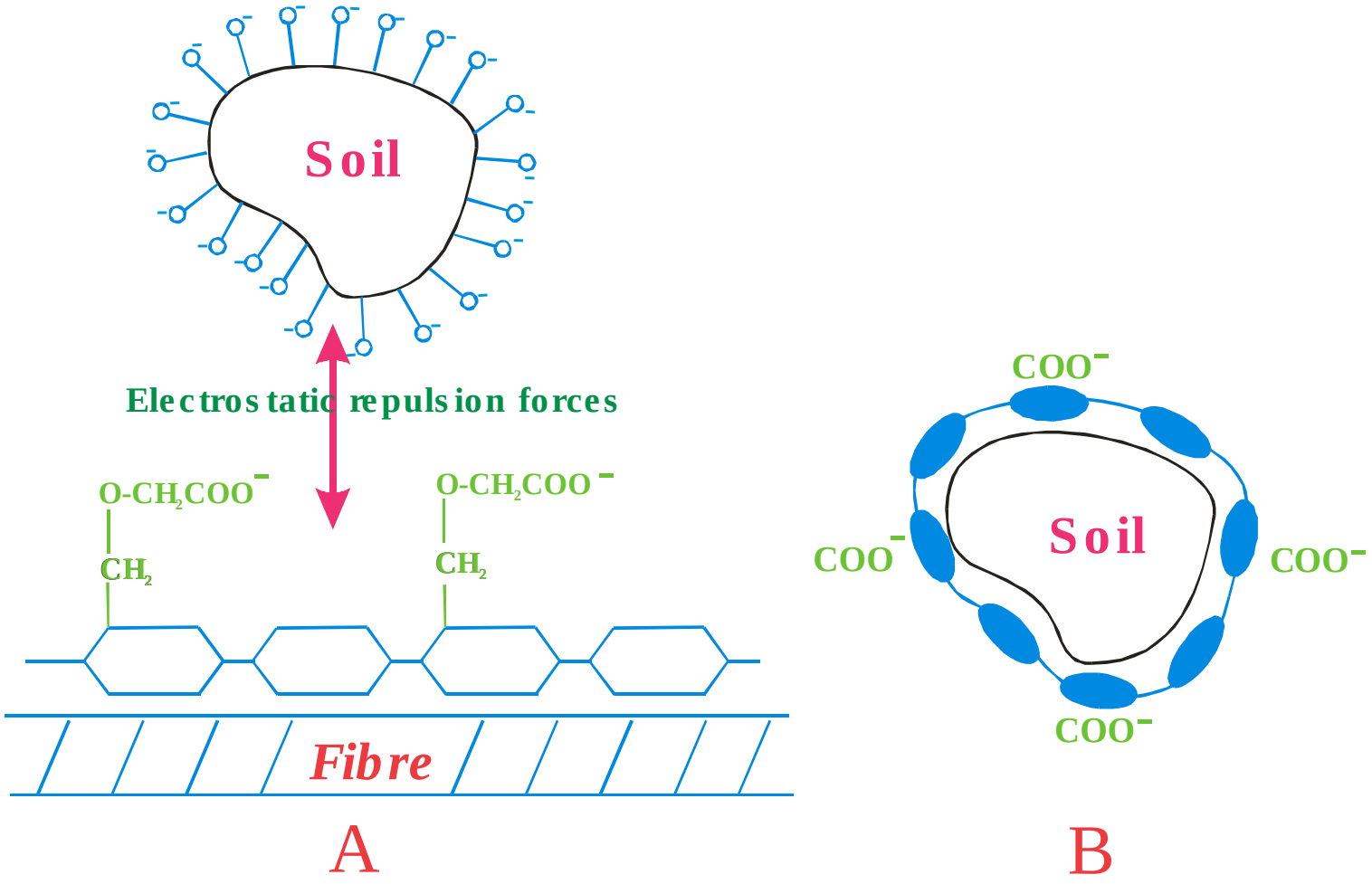


Zeolite

Sequestering agent (nitrile triacetic acid)



Chemistry and its effect on washing performance



Scheme of adsorption of carboxymethylcellulose sodium salt on fibre (**A**) and soil (**B**)

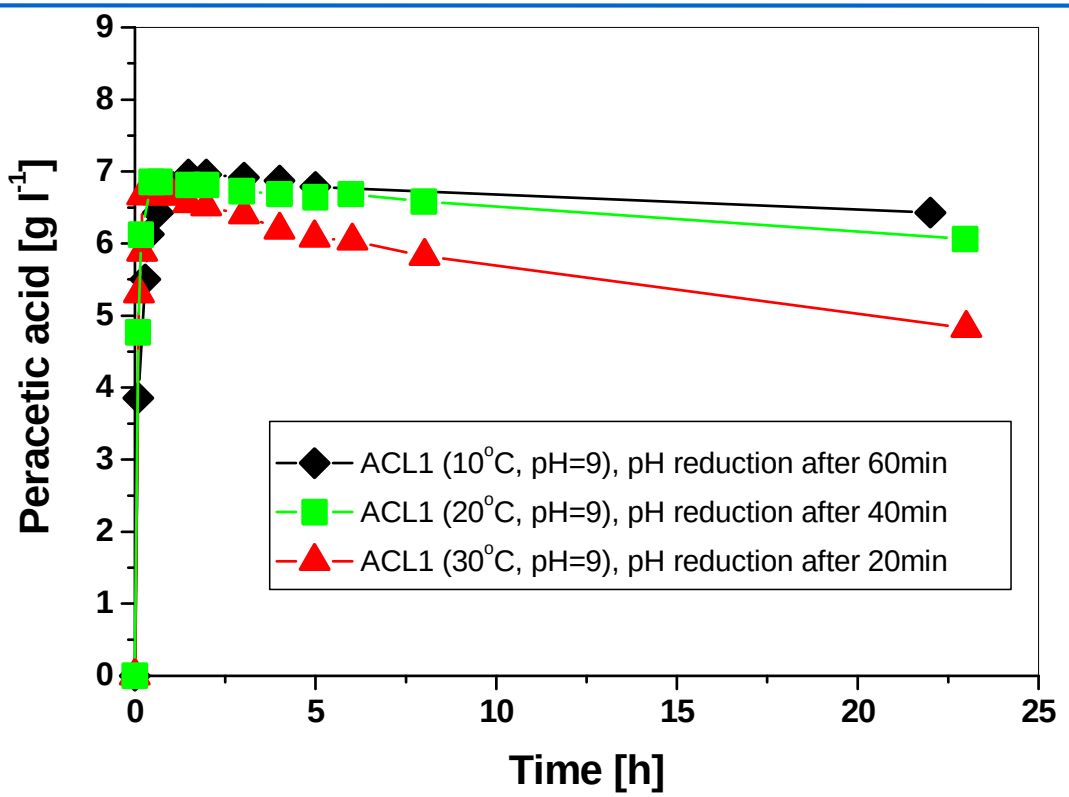
Temperature and its effect on washing performance

- At elevated temperature the kinetic energy of surfactant ions is increased and the effective removal of dirt is much easier
- At elevated temperature the sorption velocity of surfactant ions on textiles is increased
- The problem of the washing temperature in laundries should be considered in relation to disinfection
- Taking the washing quality into account , the studies done in British laundries and BLRA proved that no distinct changes in dirt removal at 60^{o}C, 65^{o}C, 82^{o}C and even above 92^{o}C were observed

Temperature and its effect on washing performance

- Our studies with linear alkylbenzene sulphonates proved that the maximum washing efficiency in the temperature range 70^{o}C – 75^{o}C was observed
- In Poland, in hospital laundries on the basis of the State Hygiene Institute and the Polish Sanitary Inspection directives the main wash should be carried out in temperatures of 92 – 95^{o}C and time 16-18 min
- What should be the proper washing temperature?

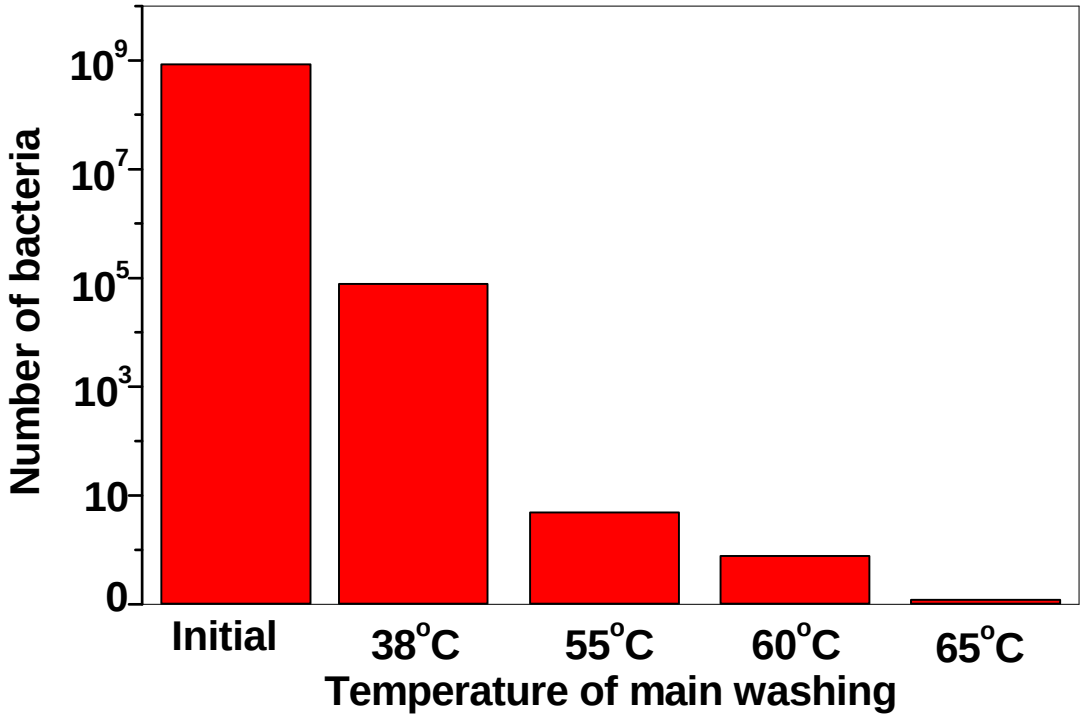
Temperature and its effect on washing performance



Influence of the reaction temperature and the timing of the pH value reduction on the concentration of the formed peracetic acid in the system ACL/H_2O_2; pH-reduction after 60min (10°C), after 40min (20°C) and after 20min (30°C)

B. Foellner, J. Bohnen, H. Kruessmann, Proceedings of wfk 40th International Detergency Conference, April 30th – May 3rd, Strasbourg, France, 2001

Temperature and its effect on washing performance



Number of viable bacteria *(Streptococcus faecalis)* on ½ square inch of textile after rinsing in dependence of main washing temperature

Kelsey, J.C., Path, M.C., Wagg, R.E., BLRA Bulletin, 9 (15), 231 – 236 (1969); 9 (16), 239 –246 (1969)

Temperature and its effect on washing performance

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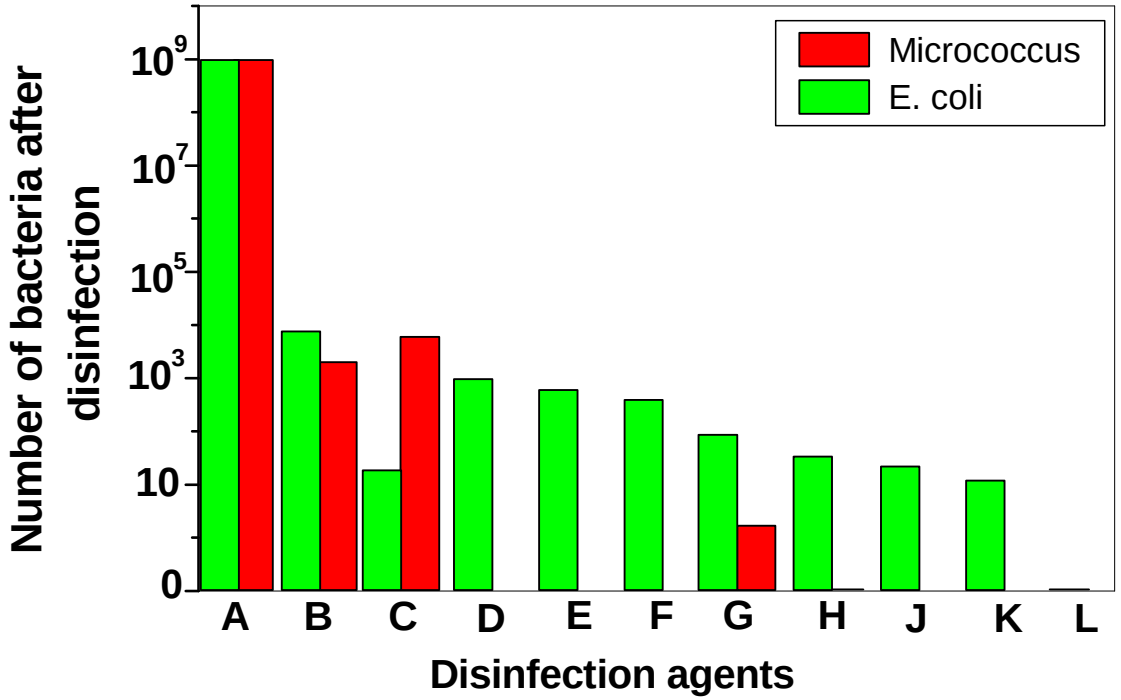
Number of viable bacteria remaining in washing liquor of various temperatures

Test number	Temperature [°C]	Minimal count of bacteria in ml	Maximal count of bacteria in ml	Average count of bacteria in ml
14	20	1200	10000000	1280000
14	30	1800	3800000	634271
14	40	700	2400000	334121
13	50	100	156000	42293
13	60	50	10000	1315
8	70	40	400	210
5	80	40	600	192
3	90	10	300	113

Gruen, L., WRP, (7), 6-10 (1979)

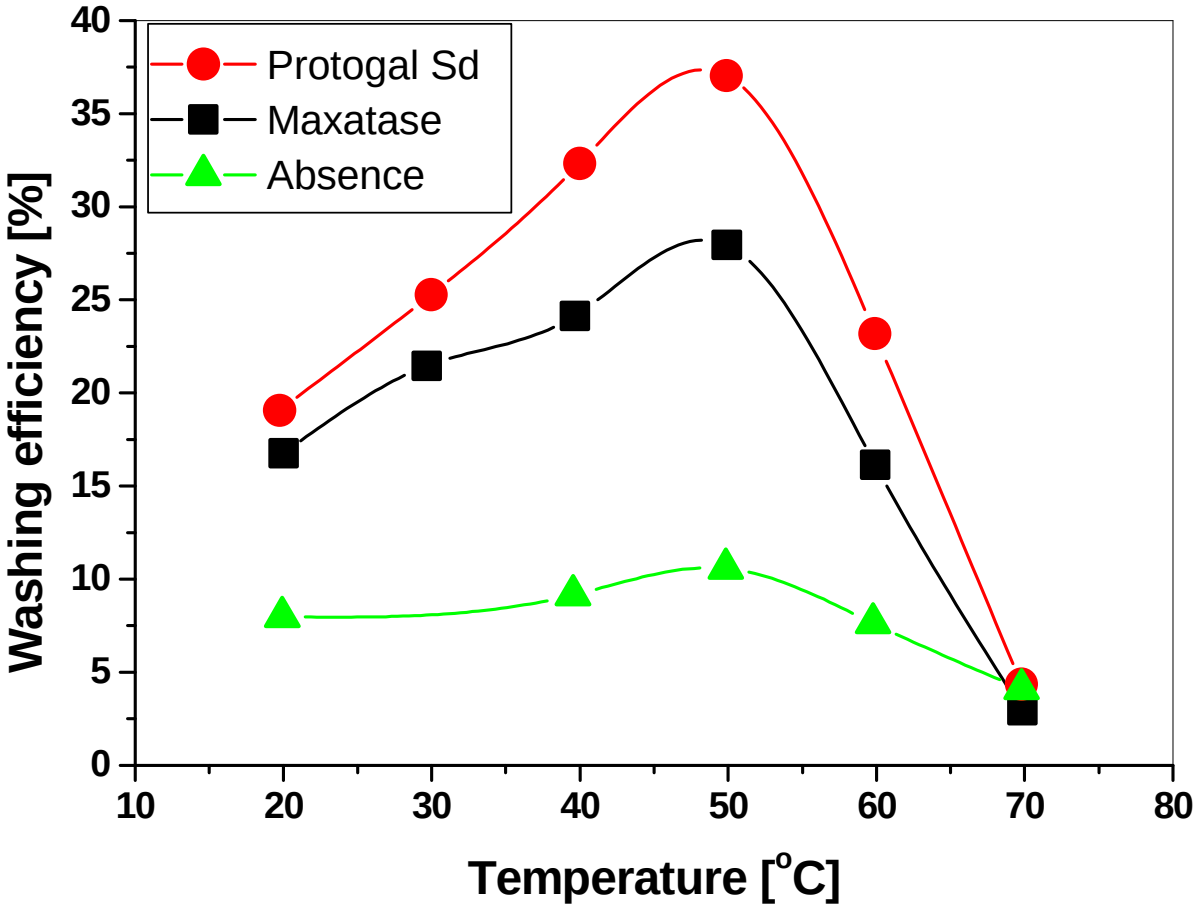
Temperature and its effect on washing performance



Number of viable bacteria on ½ square inch of textile after drum drying for blankets washed in low temperature with addition of disinfection agents: A- oryginal, B- without disinfection agents, C-L – various disinfection agents

Kelsey, J.C., Path, M.C., Wagg, R.E., BLRA Bulletin, 9 (15), 231 – 236 (1969); 9 (16), 239 –246 (1969)

Temperature and its effect on washing performance



The influence of temperature on washing efficiency
for washing processes with application of enzymatic detergents

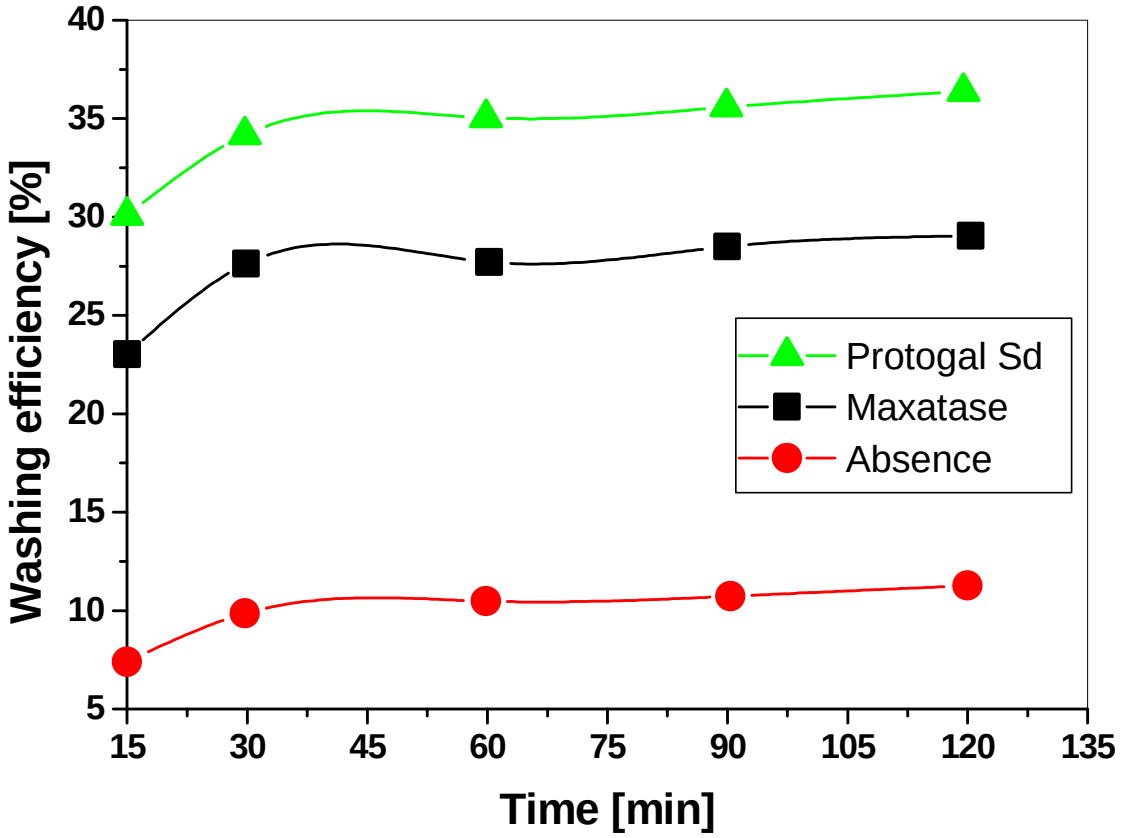
Time and its effect on washing performance

- Washing time is in reverse proportion to washing agent concentration and applied mechanics
- Washing agents require a definite contact time to ensure the proper interactions between fibre, dirt und washing agent
- With an increased time the proper balance between the fibre surface and the washing bath is achieved thus affecting the suspending power of the pigment soil and its redeposition
- The prolonged time of washing contributes to the bigger redeposition of the pigment soil causing bigger greying and the mechanical damage of textiles

Time and its effect on washing performance

- Like temperature, time in which temperature is kept can be also considered as an important factor for disinfection
- According to the BLRA studies the total time of the main wash should amount to 10 minutes + 4 minutes as “mixing time” at temperature 65^{o}C
- In washer extractors of a big load capacity 8 minutes as “mixing time” should be added (total 18 minutes)
- An increase in temperature up to 71^{o}C is associated with a decrease in basic time of wash up to 3 minutes with a “mixing time” 4 or 8 minutes, respectively

Time and its effect on washing performance



The influence of time of washing process on washing efficiency of enzymatic washing agents

Time and its effect on washing performance

No.	Stage	Water	Level	Temperature [°C]	Time [min]	Agent	Amount [g/kg]
1.	main wash 1	cold	low	40	8	Clax Build, Clax 100 OB	10.5 6.0
2.	main wash 2	cold	low	85	7	Clax Personril	7.0
3.	drain				1		
4.	rinsing 1	cold	high		3		
5.	drain				1		
6.	rinsing 2	cold	high		3		
7.	drain				1		
8.	rinsing 3	cold	medium		3	Clax Divercid I, Clax Combi citric	1.5 2.0
9.	drain				1		
10.	spinning				8		

- Clax Build, Clax 100 OB – washing agents; Clax Personril – bleaching-disinfecting agent, Clax Divercid I i Clax Combi citric – pH regulating agents in the last rinse

Technology of washing of the hospital whitework, according to Diversey; Milczyński, A., Poradnik pralniczy, Spentex ed., Łódź, 2002 r.