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*Hygiene*

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# Hygienic processing of textile in private households – a study from practice

## Summary

**Background:** Textiles to be used or needed in hygiene demanding areas like health care area (hospitals and medical practice) or food industry, must meet an appropriate microbiological quality. Measures in the course of a quality management system as for example a risk analysis should reduce mistake possibilities during reprocessing to an acceptable proportion. Reprocessing or restoring the original state of the textiles must be reproducible and understandable in each case along all single steps. Appreciable single steps of the reprocessing chain are transport of the textiles from and to the application place, if allowed sorting of textiles, disinfecting chemothermal washing procedures, drying / finishing incl. calendering, folding, supplying. In a practice study it was checked concerning microbiological quality how safe washing of textiles in private households is.

**Method:** According to specific washing programs with different temperatures (30–95°C) and detergents (color detergents and full detergents with bleaching agents) textiles were artificially contaminated with apathogenic bacteria and washed in private households. Directly after washing in wet state contact slides were used to monitor the amount of microorganisms on the textiles.

**Results:** The results indicate that even within the same assumed washing programs and detergents considerable variations appear regarding microbiological quality. Also putatively safe "hygiene programs" like 60°C in combination with full detergents did not show acceptable results.

**Conclusions:** The washing of textiles for hygiene demanding areas in private households needs to be questioned due to huge variations in reduction rates. To be able to guarantee an appropriate laundry processing the observance of all relevant process parameters like temperature and holding time, amount of detergents and disinfectants as well as liquor ratio need to be controlled and kept. Professional textile service enterprises with quality management system like the RABC system offer the necessary security and provide a relief because the core competence of many hygiene customers does not concern laundry processing.

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## Introduction

The findings of publications on the topic of laundry processing in areas with stringent hygiene requirements (e.g. healthcare sector, food industry or nursing homes) are controversial. On the one hand, in the United Kingdom the practice of nursing personnel washing their uniforms at home (i.e. in a private household) is not considered to be a problem since the requisite standard of hygiene with reduction in the number of pathogens surviving the washing process is thought to be assured by subsequent drying or ironing [1]. Such statements must be viewed in a critical light alone for the reason that the situation prevailing in any individual case is not taken into account. In a private household it is in general difficult to regulate, as necessary, a washing machine, wash programme, detergents, disinfectants, load, extent of textile soiling, liquor ratio, temperature and holding time, or often these are not tailored to the hygiene results aspired to. Moreover, in the United Kingdom

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nurses don their uniforms already before going to work and remove them only after returning home. How hygienic and safe is the practice of nurses wearing their uniforms on the journey home, when visiting a supermarket or what the implications does this have for other members of the household, e.g. children, is something that is not discussed.

On the other hand, there is growing evidence of the need to supply such hygienically demanding areas with textiles that have been processed to a high standard under strict conditions, since textiles cannot be ruled out as potential 'vectors' of pathogens [2,3].

If laundry that must meet rigorous hygiene demands is processed by professional textile-processing service providers, a quality management system, including risk analysis as per DIN EN 14065, should be introduced to evaluate all process steps in terms of the risk of microbial contamination they pose [4].

A major problem with hygienic evaluation of processing procedures in a private household is that reliable and reproducible data can only be achieved if all relevant parameters are kept as constant as possible. Accordingly, in such studies often washing machines with a known and as far as possible constant performance are used. The load is pre-washed in accordance with the pertinent standards and placed in the machine in a clean state while observing a particular loading pattern. Sometimes an artificial soil is used. The detergent and disinfectant agents are weighed and dosed exactly as directed by the manufacturer. The results are evaluated only if specific fluctuation tolerances with regard to the incoming water supply, temperature and holding time were kept. Such an approach is needed to assure scientifically evaluable results. But it is precisely this approach that masks the situation in practice. The main drawback of processing laundry in a private household derives from the enormous fluctuation range of the aforementioned parameters [5]. Our own, unpublished, studies indicate that after setting a 60°C programme, washing machines in reality briefly reach temperatures between 45 and around 55 °C. The holding times are between around 5 und 20 minutes, and no constant temperature is maintained, instead fluctuations of over 10 °C can arise because of switching the heating on and off. The liquor ratio (ratio of load quantity in kilograms to water quantity in litres) can generally only be roughly estimated. Since the incoming water supply is subject to fluctuations (also because of the automatic control used in some washing machines), assurance of a defined detergent and disinfectant concentration (e.g. grams per litre of washing liquor) is questionable. Furthermore, there are variations in the load quantity and extent of soiling of laundry, resulting in different quantities of bound liquor and different degrees of disinfectant inactivation. In addition, cotton binds more liquor than e.g. polyester textiles, in turn having an impact on the washing mechanics. Against a background of the problems outlined above, Niederrhein University initiated a Hygienic Wash Project simulating the conditions under which textiles are washed in a private household.

The only advance specifications were microbial contamination and detailed documentation of the procedure to be used (machine, detergent type and quantity, load and selected programme). All participants were requested to wash their laundry as they deemed fit. To give participants an understanding of hygienic laundry and of washing in a private household as well as of how to handle contamination materials and contact plates training, with practical exercises, was given over several days. Hence it can be assumed that the results obtained are of a robust nature.

## Materials and Methods

### Microorganisms

To rule out as far as possible a health risk to the project participants, 3 bottles of Actimel® with a total of $3 \times 10^{10}$ bacteria (*Lactobacillus casei*) were used to investigate the reduction factors in the different wash cycles for each wash test. Contamination of textiles with the bacteria was checked using contact plates.

### Cultivation of microorganisms and cultures

The microorganism cultures (Actimel®) were purchased on the consumer market and directly applied to the textiles to be washed. After washing the laundry, microorganisms were cultured on contact plates for 3–5 days at 21 °C.

### Recovery of microorganisms

Trypticase soybean agar (article number 860, heipha Dr. Müller GmbH), also known as Tryptic Soy Agar (TSA) or Soybean Casein Digest Agar (CSA), is a universal complex medium for cultivation and isolation of fastidious bacteria, yeasts and moulds. In its basic composition, trypticase soybean agar meets the recommendations of the current European Pharmacopoeia (EP) and that of the United States Pharmacopoeia (USP). To inactivate any residual disinfectant, lecithin, Tween 80 and histidine were added to the medium. Composition (per litre): 15 g trypticase, 5 g soybean agar, 5 g sodium chloride, 0.7 g lecithin, 5 ml Tween 80, 1 g histidine, 15 g agar (pH 7.3 ± 0.2). (Since growth was noted on several contact plates it was assumed that any disinfectant residues had been inactivated).

### Washing machines

The reference washing machine used in the laboratory was a Wascator, FOM 71 MP – Lab (Electrolux). In the private households the project participants' washing machines were used.

### Textiles/load

In the laboratory 2 kg bed sheets (cotton) were used for each wash cycle (i.e. washing process). For the wash cycles in the private households on average 2 kg textiles (bed sheets, T-shirts and handtowels) were used.

## Results

To begin with, 30 °C and 40 °C wash cycles were run in the laboratory reference machine. The detergent used in each case in the reference cycle was a colour industrial detergent and a full industrial detergent (with bleaching agents). The results are given in Tables 1 and 2.

In the 30 and 40 °C cycles run in the reference laboratory machine both test and external microorganisms survived exposure to the colour detergent. As expected, reduction in the number of test microorganisms was greater on using the full detergent than when using the colour detergent.

After 60 °C cycles no microorganisms were found on using either the full or colour detergent (data not shown).

But the cycle results obtained in the private household setting painted a totally different picture. Even after supposedly high temperatures large numbers of microor-

Table 1: Results of the reference washing machine at 30 °C by using color detergent [CD] and full detergent [FD] (each: 100 g powder, 26 litre total water consumption, 35 min total washing time).

| Number contact slides [N] | Test bacteria CFU per dm² | Foreign microorganisms CFU per dm² | Before [b] or after [a] washing |
|---|---|---|---|
| 5 | >2000 | 4–16 | b |
| 5 | >2000 | 4–44 | b |
| 5 | >2000 | 8–28 | b |
| 5 | >2000 | 0–16 | b |
| 5 | >2000 | 24–36 | b |
| 5 | >2000 | 36–52 | b |
| 5 | CD: 128 – >2000; FD: 0 | CD: 60–156; FD: 4–16 | a |

Table 2: Results of the reference washing machine at 40 °C by using color detergent [CD] and full detergent [FD] (each: 100 g powder, 26 litre total water consumption, 35 min total washing time).

| Number contact slides [N] | Test bacteria CFU per dm² | Foreign microorganisms CFU per dm² | Before [b] or after [a] washing |
|---|---|---|---|
| 5 | >2000 | 4–24 | b |
| 5 | >2000 | 4–12 | b |
| 5 | >2000 | 6–24 | b |
| 5 | >2000 | 4–28 | b |
| 5 | >2000 | 4–8 | b |
| 5 | >2000 | 0–44 | b |
| 5 | CD: 0–8; FD: 0 | CD: 0–12; FD: 0–16 | a |

ganisms were detected in some cases after washing (Table 3).

As expected, the cold wash cycle (colour detergent, 20 °C, 60 min) produced reduction values so low that they could hardly be measured. In the 30 °C cycles with colour detergent, it was mainly the test bacteria and a very small number of external microorganisms that were found. Using the 30 °C cycle and a full detergent, a slight increase was noted in the number of external microorganisms. Conversely, in the 40 °C cycle with colour detergent there was slightly greater reduction of the test bacteria with correspondingly low colony forming unit (cu) values of external microorganisms. The 40 °C cycle with full detergent reduced the test bacteria, but the proportion of external microorganisms continued to rise.

A measurable reduction in the test bacteria for the 60 °C cycle tested (and the 75 °C cycle) with colour detergent was also accompanied by a slight rise in external microorganisms. It was possible to further reduce the test bacteria on using a full detergent in the 60 °C cycle. But the proportion of external microorganisms continued to be slightly higher.

In the 90 and 95 °C cycles there was a marked reduction of the test bacteria both with colour detergent and with full detergent. Overall, few surviving microorganisms were found, with on average more external microorganisms being identified.

## Discussion

The results are alarming and reflect the problems arising from hygienic processing of textiles in a private household. In view of the myriad types of washing machines, different washing processes / cycles, detergents, loading patterns and extent of soiling of laundry, it appears to be virtually impossible to obtain satisfactory and reproducible hygiene performance when processing laundry in a private household. Moreover, individual habits (e.g. detergent dosage, machine care, use frequency, choice of programme, etc.) result in even what is thought to be similar cycles becoming unique in terms of reduction factors. It appears impossible to control, let alone validate, a washing process in a private household in view of the prevailing conditions. There is a complete absence of the prerequisites required for a quality management system or for adequate risk analysis.

The assumption often encountered [6,7,8] whereby 60°C cycles in domestic washing machines together with a full detergent in general assures adequate hygiene cannot be confirmed. Rather, it must be assumed that uncontrolled processes, as used in private households, are a black box in terms of the microbiological quality of textiles.

Furthermore, it must be borne in mind that in all wash tests lactic acid bacteria (*Lactobacillus casei*) from fresh yoghurt cultures (not dried or fixed) were used. While compared with conventional biomonitors (thermo- and chemotolerant bacteria that are fixed with blood on cotton cloths), these bacteria, which are comparatively easy to wash away and inactivate, are suitable for comparative testing, the requirements in everyday practice (e.g. bacteria fixed because of dried soils, biomonitors with blood-fixed bacteria) are in general much more demanding [9]. In the interest of health protection it was not possible to use biomonitors with human pathogenic bacteria in these tests.

There is, no doubt, reason to ask whether textiles washed at home pose a serious risk of infection. But in the majority of cases this cannot be assumed. However, if the textiles are intended for use in areas sub-

Table 3: Numbers of CFU after washing in private households by using color detergent [CD] and full detergent [FD] at different temperatures.

| Number contact slides [N] | Test bacteria CFU per $dm^2$ | Foreign microorganisms CFU per $dm^2$ | Remarks: duration, detergent, program, temperature, type and amount of load |
|---|---|---|---|
| 5 | 1060,800,1640,1680,1300 | 36,24,12,24,24 | 60 min, CD, "cold", 20°C, towels, 1 kg |
| 5 | >2000,1604,1900,1772,1548 | n.e. | 14 min, CD, "extra rinse", 30°C, towels, 1 kg |
| 5 | >2000 | 32,44,20,24,28 | 120 min, CD (liquid), "normal", 30°C, cotton, 6 kg |
| 5 | 3024,2836,2820,3132,2832 | 0 | 20 min, CD (liquid), "sensitive", 30°C, towels, 1 kg |
| 5 | >2000 | 52,40,56,40,48 | 95 min, , CD "easy care", 30°C, cotton, 2,5 kg |
| 5 | 496,88,276,n.e.,n.e. | n.e. | 95 min, CD, "easy care", 30°C, cotton, 2,5 kg |
| 5 | 172,156,96,216,152 | 148,184,196,252,180 | 90 min, FD, "normal 30°C", towels, 3 kg |
| 5 | 92,148,68,48,44 | 156,172,112,128,116 | 90 min, FD, "normal 30°C", T-shirts (cotton), 4,1 kg |
| 5 | 1744,1488,>2000,1376,1344 | 344,204,328,188,280 | 120 min, FD, "normal", 30°C, cotton, 6 kg |
| 5 | >2000,>2000,>2000,>2000,1868 | 20,24,8,12,36 | 30 min, FD, "normal", 30°C, cotton, 5 kg |
| 5 | >2000,>1248,>2000,1848,1520 | n.e. | 38 min, CD, "wool", 40°C, towels, 2 kg |
| 5 | 264,228,208,220,200 | 4,16,24,12,12 | 20 min, CD, "easy care", 40°C, towels, 1 kg |
| 5 | 820,412,724,712,440 | 0 | 23 min, CD, "sensitive", 40°C, towels, 2 kg |
| 5 | >2000 | 8,4,0,4,0 | 116 min, CD (liquid), "colored", 40°C, cotton, 2,6 kg |
| 5 | 820,908,1064,404,1068 | 0,0,4,0,24 | 116 min, CD (noir, liquid), "colored", 40°C, cotton, 2,1 kg |
| 5 | >2000,1544,>2000,n.e.,n.e. | 12,8,8, n.e.,n.e. | 135 min, FD, "normal", 40°C, cotton, 2,5 kg |
| 5 | 40,20,40,16,8 | 184,48,124,76,116 | 120 min, FD, "normal", 40°C, cotton, 6 kg |
| 5 | 24,56,28,48,36 | 4,0,0,0,4 | 70 min, FD (liquid), "colored", 40°C, cotton, 2,6 kg |
| 5 | 256,264,240,308,368 | 32,32,36,44,368 | 95 min, FD, "short", 40°C, cotton, 5 kg |
| 5 | 232,408,260,332,796 | 200,200,300, n.e., n.e. | 70 min, CD, "colored", 60°C, towels, 1 kg |
| 5 | >2000,>2000,1520,1932,>2000 | 0 | 71 min, CD (liquid), "easy care", 60°C, towels, 1 kg |
| 5 | 336,360,384,580,544 | 0,0,12,4,12 | 131 min, CD, "hot eco", 60°C, cotton, 3,7 kg |
| 5 | 336,360,384,580,544 | 0,0,12,4,12 | 131 min, CD, "hot eco", 60°C, cotton, 3,7 kg |
| 5 | 792,736,516,532,628 | 204,8,300,300,400 | 63 min, CD, "chemo-thermal", 60°C, towels, 2 kg |
| 5 | 92,68,48,128,136 | 48,36,56,108,68 | 90 min, FD, "normal 60°C", towels, 1,5 kg |
| 5 | 44,76,56,28,36 | 16,24,20,12,28 | 90 min, FD, "normal 60°C", T-shirts (cotton), 1,7 kg |
| 5 | 232,924,828,484,724 | 0,4,200,200,0 | 54 min, FD, "table linen", 60°C, towels, 1,4 kg |
| 5 | 8,8,20,4,4 | 56,68,76,76,128 | 120 min, Fd, "normal", 60°C, cotton, 6 kg |
| 5 | 136,152,152,116,144 | 0,8,4,0,4 | 75 min, FD, "sensitive", 60°C, towels, 1 kg |
| 5 | 308,424,432,224,648 | 208,100,200,100,100 | 54 min, FD, "colored", 60°C, towels, 1 kg |
| 5 | 308,240,160,420,212 | 184,152,140,220,76 | 145 min, FD, "normal", 60°C, cotton, 5 kg |
| 5 | 108,160,68,160,0 | 8,12,8,16,0 | 130 min, FD, "normal", 60°C, cotton, 5 kg |
| 5 | 1032,992,972,944,972 | 4,28,40,20,16 | 54 min, CD, "table linen", 75°C, towels, 2 kg |
| 5 | 16,28,16,28,12 | 100,0,100,200,0 | 60 min, CW, "hot colored wash", 90°C, towels, 2 kg |
| 5 | 28,0,16,36,0 | 12,24,16,48,28 | 90 min, FD, "normal 90°C", towels, 2 kg |
| 5 | 0,0,20,0,0 | 12,16,0,36,28 | 90 min, FD, "normal 90°C", T-shirts (cotton), 2,7kg |
| 5 | 12,0,4,8,0 | 0,0,0,0,4 | 116 min, FD (liquid), "hot", 90°C, cotton, 1,9 kg |
| 5 | 0,0,0,4,0 | 0 | 116 min, FD (liquid), "hot", 90°C, cotton, 2,7 kg |
| 5 | 84,80,100,92,96 | 4,0,0,0,8 | 30 min, CD, "hot colored wash", 95°C, towels, 2 kg |
| 5 | 0 | 40,16,16,32,24 | 135 min, FD, "normal", 95°C, cotton, 6 kg |
| 5 | 0 | 664,660,384,336,288 | 20 min, FD, "hot colored wash", 95°C, towels, 2 kg |
| 5 | 0,0,0,16,20 | 28,28,32,20,60 | 95 min, FD, "short", 95°C, towels, 5 kg |
| 5 | 16,32,32,8,12 | 28,8,40,40,40 | 155 min, FD, "normal", 95°C, cotton, 5 kg |

n.e.: evaluable

ject to stringent hygiene requirements, such as in the healthcare sector, food industry or nursing homes, the possibility of pathogen transmission via the 'vector' textiles must not be discounted.

Noteworthy is that at low temperatures (20–40 °C) because of the high number of test bacteria comparatively fewer external microorganisms were noted. In high-temperature processes in which the test bacteria had been markedly reduced, the number of external microorganisms detected rose. That trend can be explained by the fact that the external microorganisms were overgrown by the high number of test bacteria or their growth had been inhibited. Whether the external microorganisms were introduced in the laundry or had already been present in the machine in biofilms was not investigated.

## Conclusion

There is still much to be done to gain a better understanding of the fact that even use of products featured on the official lists of the Robert Koch Institute (RKI) and the Association of Applied Hygiene (VAH) does not produce the desired results if the process parameters given in the lists are not observed.

These parameters include

– temperature, incl. holding time (time range during which this temperature is reached and maintained),
– detergents and disinfectants as well as washing and disinfectant processes deemed effective
– dose (gram per litre liquor) and
– liquor ratio (ratio of load to water [10, 11].

All parameters must be regularly checked and recorded.

If it is not possible to control washing processes to ensure that all relevant parameters are being observed, alternative liquors should be found as quickly as possible to minimise infection risks. Professional textile service providers have facilities for providing reproducible and client-specific hygienic textiles in line with the pertinent requirements.

## Conflict of Interest

The authors declare that there is no conflict of interest as understood by the International Committee of Medical Journal Editors.

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