Determining the Hygiene of Laundering Industrial Textiles in Slovenia, Norway and Denmark

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Since textiles sent to industrial laundries contain all sorts of pathogenic organisms, it is important that laundering results not only in an appropriate cleaning effect, but a satisfactory disinfecting one as well. Although the procedure of laundering itself is most important for achieving disinfection, it is also essential to maintain an appropriate hygiene level in the segments of the process that treat cleaned and disinfected laundry. This should be done in order to prevent recontamination by environmental viable microorganisms, from manual handling of textiles in the processes such as ironing, folding, packing etc. The investigation presented evaluates the hygiene level of hospital textiles in Slovenia and Denmark, as well as the hygiene level of different textiles from different segments of the food-processing industry in Slovenia and Norway. The German RAL-GZ 992 quality assurance system, based on the requirements of the Robert-Koch Institute, the European standard RABC and the HACCP-principles are used to determine the hygiene level of the laundered textiles in Slovenia. For the hygiene level of the Danish laundries, the total bacteria count, and enterobacteria count are determined at control points, while the aerobic count, coliform count and E.coli count are determined at control points for the hygiene level of the Norwegian laundries. The examination shows that using regular cleaning and disinfecting measures by all staff is of crucial importance in achieving an appropriate hygiene level and that the disinfection effect of the laundering procedure is the preliminary condition for disinfected textiles.
Key words: *laundry hygiene, hospital textiles, food-processing industry, occupational health*

1. Introduction

The main aim of washing laundry is to remove soils and microorganisms from infected and dirty textiles and obtain clean, fresh and disinfected textiles, ready for use. Textiles undergo laundering processes which include soil removal with special laundering agents, bleaching, disinfecting, and finally neutralizing and rinsing. As textiles from hospitals may contain all sorts of pathogenic bacteria, fungi and viruses, it is essential that the laundering process results not only in a cleaning effect, but in an anti-microbial one as well [1]. Since users of hospital textiles are often patients with weaker immune system, it is recommendable that best practice and common sense be employed when washing and disinfecting hospital textiles. The food processing industry is a very diverse segment of industry which includes different branches such as animal slaughter, prepara-

tion of meat products, preparation of intermediate food products, catering trades etc. The textiles used in the food processing industry are supposed to protect against meat contamination from microorganisms, as well as to protect the workers from microorganisms contained in the carcasses, faeces, bone dust, blood clots etc. [2]. In the catering industry, textiles are used to cover tables in restaurants and for other, mostly aesthetic, purposes. The hygienic aspect of textiles is an important factor in preventing infections of laundry workers and users of food products. Most people assume that the laundry returned to them is actually clean and, therefore, safe for use. However, this may not be always so as the dirt may certainly be removed, but textiles are most often far from sterile. Experience encourages all infection control teams to take laundering very seriously [3-13]. Inappropriately disinfected textiles are one of the possible sources of nosocomial infections of patients, as is evident from the results of many published investigations. There are reports of hospital textiles being the source of nosocomial infections with *streptococci* [10], enterococci [14], *Bacillus cereus* [15], staphylococci [16] and coliforms [17]. There is also a risk of infecting the staff in hospital wards and laundries in dealing with dirty laundry. There are some documented cases of infections with scabies [18], fungi [19], salmonellas [20], gastroenteritis viruses [21], hepatitis A viruses [22], coxiellas [23] etc.

Although hygiene aspects are obviously most important for these textiles, the quality of laundering is important for aesthetic purposes as well [24-26]. There are different systems of evaluating the hygiene level of laundered textiles.

1.1. Regulations of the Robert-Koch institute (RKI-regulations)

RKI-regulations [27] are German obligatory hygiene regulations for textiles from medical establishments and laundries that contain valid laundering procedures and conditions for hospital textiles. According to the RKI-regulations, hospital textiles must be clean and must not contain any pathogenic microorganisms. There are two important tests for evaluating the hygiene level in hospital laundries according to the RKI-regulations:

- The disinfection effect of a laundering procedure for hospital textiles is tested by using two standard bioindicators: *Enterococcus faecium*, ATCC 6057 and *Staphylococcus aureus*, ATCC 6538. Cotton textile substrates (1cm^2) are used as carriers of the suspension of defibrinated sheep blood and microorganisms. The laundering procedure must enable the reduction of 100,000 CFU/mL for both standard bacteria.
- Surface sampling using RODAC-agar plates, conducted on 10 random samples of ironed and folded hospital textiles must not exceed the following limit: 9 out of 10 samples must not contain more than 2 CFU/10 cm^2. There must not be any pathogenic microorganisms on the sampled textiles.

1.2. EN 14065: The RABC – Risk analysis and biocontamination control

On the 23rd of September 2002, the European Committee for Standardization (CEN) approved a standard, based on the RABC principles, for laundry processed textiles [28]. This document provides a management system that uses the principles of risk analysis and biocontamination control system, based on preventive measures. It enables laundries to continuously assure the microbiological quality of laundered textiles, especially for textiles used in specific sectors, such as pharmaceuticals, medical instruments, food, healthcare and cosmetics. A control point (CP) is any point or step in the process to which control is applied, in order to contain, eliminate or reduce the biocontamination risk.

1.3. The HACCP-principles – Hazard analysis and critical control points

On the 14th of July 1993, the European Committee accepted a new directive - EG Richtlinie 93/43/EWG for Hygiene in the Food Industry, based on the HACCP system [29-31]. The HACCP system is a quality system enabling companies to formulate food safety policies and is based on establishing, documenting and maintaining a system of ensuring that all the known potential hazards are identified, and all relevant hazards controlled in such a manner that company products could not harm the consumer. Critical control point (CCP) is the point, procedure or stage in the food chain at which control can be applied, and is essential to prevent any food safety hazard or reduce it to an acceptable level [29, 32]. Textiles used in the food Industry (i.e. working clothes, towels etc.) are classified as one of these CCPs.

1.4. The RAL-GZ 992 – Hygiene assurance for hospital textiles and textiles in the food-processing industry

In the year 1986, directions for the laundering hygiene RAL-GZ 992/2 for hospital textiles were issued by RAL [33-34], the German Institute for Quality Assurance and Certification. These directions are valid as important recommendations for laundries in the European Union. The Research Institute Hohenstein, Germany authorized by RAL, issues the Certificates of the laundering quality and hygiene of hospital textiles (RAL-GZ 992/2), which include RABC principles and are based on the regulations of the German Robert-Koch institute [35]. Additional directions for the laundering quality and hygiene for textiles from the food-processing industry according to RAL-GZ 992/3 were issued in 1998. Retaining the Certificates depends upon the unannounced annual inspections of the laundering and disinfecting quality

and the hygiene levels in the laundries, according to standard methods and in comparison with the limited values, Tab.1). There are several CPs in laundries that are essential to control in order to reduce bacterial contamination, Tab. 1. They include evaluating the laundering procedure using standard bioindicators, surface sampling using the RODAC-agar plates of textiles, technical equipment, storage shelves, and transport vehicles, as well as the hands of workers and microbiological evaluation of water samples. The hygienic state of the CPs is evaluated as the result of random external control.

An overview is presented of the hygiene level of the Slovenian and Danish laundries that wash hospital textiles as well as an overview of the Slovenian and Norwegian laundries that wash textile from the food-processing industry.

2. Methods

2.1. Assessment of laundering hygiene in Slovenia

2.1.1. Assessment of the disinfection effect of the laundering procedure

Enterococcus faecium and *Staphylococcus aureus* were used as bioindicators and were inoculated into defibrinated sheep blood in order to determine the efficiency of the chemo-thermal or thermal disinfection during the investigated laundering procedures, according to the hygiene assurance RAL-GZ 992/2 for hospital textiles. *Enterococcus faecium* and *Staphylococcus aureus* are standard bioindicators used in European tests for determining basic bactericidal disinfectant efficiency, with the aim of achieving a reduction of 100,000 CFU/mL according to the RKI regulations [27]. This method of bioindicator preparation was described before [2, 4, 27]. The bioindicators were incorporated into the tested laundering procedures (washing, rinsing and wringing phases) at the laundries, then taken out and brought to the lab: They were put into 40 mL of tryptic soy broth (TSB) for 4 days at 36 °C (Incubator, Wtb Binder) after which 1 mL of the homogenized suspension was spread onto the following agars: bile esculin azide agar for *Enterococcus faecium* and Baird-Parker agar for *Staphylococcus aureus* incubated for 24 hours at 36 °C. The presence of *Enterococcus faecium* was confirmed by olive green to black col-

Tab.1 Tolerance values of critical control points according to the RAL-GZ 992/2 for hospital textiles and the RAL-GZ 992/3 for textiles from the food-processing industry

CP	RAL-GZ 992/2	RAL-GZ 992/3
Ironed and folded textiles [b]	9 out of 10 samples should not contain more than 20 CFU [c] /dm^2 [a]	9 out of 10 samples should not contain more than 50 CFU/dm^2
Washing procedure	No growth of bio indicators [a]	No growth of bio indicator
Damp textiles	< 30 CFU/dm^2	< 100 CFU/dm^2
Tap washing water, softened water, rinsing water	< 100 CFU/mL [d]	< 100 CFU/mL
Technical equipment (washing machines, sorting and conveyer belts)	< 100 CFU/dm^2	< 100 CFU/dm^2
Storage shelves/transport (flatwork ironer shelves, folded laundry shelves, side wall in transport vehicles)	< 100 CFU/dm^2	< 100 CFU/dm^2
Hand hygiene (workers at sorting conveyor belts, flatwork ironers and folding tables)	< 100 CFU/dm^2	< 100 CFU/dm^2

[a] limit values: fixed by the German Robert-Koch institute.

[b] The RODAC-agar plates used for surface sampling of ironed and folded textiles should not contain pathogenic and potentially pathogenic microorganisms such as *Escherichia coli*, *Enterobacter cloaque* etc.

[c] CFU/dm^2 (colony forming units) = number of colonies (bacteria, fungi) formed on the RODAC-agar plates after being incubated for (48±4) hours at 37 °C calculated to an area of 1 dm^2.

[d] CFU/mL = number of colonies (bacteria, fungi) formed in 1 mL water samples after being incubated for (24±4) hours at 37°C or in 1 mL water samples after being incubated for (72±4) hours at 22°C

onies. Black, shiny colonies with a halo confirmed the presence of *Staphylococcus aureus.* Disinfection was successful when no growth of colonies in any agars was detected, thus achieving the necessary reduction of 100,000 CFU/mL for bacteria.

2.1.2. Assessment of water samples

Water samples were taken in the laundries from the water before softening, after softening and rinsing water, according to the hygiene assurance RAL-GZ 992/2 for hospital textiles. 200 µL of each water sample were placed on trypcase soy agar. Two samples were prepared for each main sample – one for the incubation at 22 °C for 72 h, the other for the incubation at 37 °C for 24 h. CFU was determined, then identification by general microbiological methods, as noted in section 2.1.4 [2,4].

2.1.3. Assessment of plate counting agar samples

Counting plates containing the RODAC agar were used for surface sampling at the following control points in the laundries: textiles (ironed and folded textiles, damp textiles), technical equipment (washing machines, sorting and conveyer belts), storage shelves/ transport (flatwork ironer shelves, folded laundry shelves, side wall in transport vehicles), hand hygiene (workers at sorting conveyor belts, flatwork ironers and folding tables) according to the hygiene assurance RAL-GZ 992/2 for hospital textiles. The RODAC-agar plates were applied to all surfaces with an even pressure distributed over the whole plate for 10 s. The mean surface area of each plate was 25 cm^2. The count agar plates containing the RODAC agar were incubated at 37 °C for 48 h. After the incubation period, the CFU was determined and identification of the formed colonies was conducted by general microbiological methods, as noted in section 2.1.4 [2, 4].

2.1.4. General microbiological methods for identification

All formed colonies were analyzed using general and specific microbiological methods listed below. Any presence of isolates from the family of *Enterobacteriaceae* was confirmed by the Gram's stain, catalase activity, oxidase activity and by growth on the Endo agar, the VRB-agar and the VRBD-agar. Conformation of *Pseudomonas aeruginosa* was characterized by the Gram's stain, catalase activity, oxidase activity and by growth on the cetrimid agar. Any presence of *Stapylococcus sp*. water isolates was confirmed by the Gram's stain, catalase activity, oxidase activity, coagulase activity, as well as growth on the Baird-Parker agar and the Columbia blood agar. *Enterococcus sp*. isolates were characterized by the Gram's stain, catalase activity, oxidase activity, pyrase activity and by growth on the bile esculin azide agar and the Columbia blood agar. Conformation of *Micrococcus sp*. isolates was confirmed by the Gram's stain, catalase activity, oxidase activity and by the absence of growth on the OF-medium under anaerobic conditions. *Corynebacterium sp*. isolates were characterized by Gram's stain, catalase activity, oxidase activity and by microscopy. Gram positive aerobic spore forming bacilli were confirmed by the Gram's stain, catalase activity and by growth on the TSA-agar after thermal treatment of samples (10 min, 75 °C). The presence of yeasts and fungi were characterized by visual observation of hypheae or the presence of yeast cells [2, 4].

2.2. Assessment of the laundry hygiene in Denmark

The control points noted in Tab.2 of five ironed and folded random hospital textiles were evaluated as control points as the result of random external control. Total bacteria count and enterobacteria count were evaluated and points given according to the scale.

2.2.1. Sampling and assessment of control points

For hygiene evaluation, five random textiles were chosen. Each textile was swabbed two times - once

Tab.2 Tolerance values of control points for hospital textiles used in Denmark

Category	TPC	E
5 random ironed and folded hospital textiles	Less than 2 cfu/cm^2 gives 15 points. More than 2 cfu/cm^2 gives 0 points.	0 cfu/cm^2 gives 15 points. Any number cfu/cm^2 gives –10 points.
Scale		
150-135 points	excellent	Hygiene level approved
134-120 points	good	Hygiene level approved
119-105 points	neutral	Hygiene level approved
104-90 points	bad	Hygiene level not approved
Below 90 points	serious	Hygiene level not approved

using the Hygicult TPC slide monitor and once using the Hygicult E slide monitor. The Hygicult TPC slide contained total plate count agar on both sides, whilst the Hygicult E slide contained modified VRB agar on both sides. Sampling was performed by pressing both sides of each monitor firmly against the surface for 3-4 sec. After sampling both slides were incubated at 37 °C. The colonies formed on the Hygicult TPC slide were counted after 24 h and the red colonies formed on the Hygicult E slide were counted after 48 h.

2.3. Assessment of the laundry hygiene in Norway

The control points noted in Tab.3 were evaluated as the result of random external control conducted 2 to 6 times per year, according to the RABC standard protocol. The aerobic count, coliform count and *E. coli* count were evaluated according to the limit values (Tab.3) determined by the Robert-Koch Institute. If a particular laundry washes hospital textiles as well as the textiles from the food-processing industry, the limit values for hospital textiles according to the Robert-Koch Institute should be used.

2.3.1. Sampling of control points

The control points were swabbed using RediSwab screw-cap tubes filled with 15 mL of neutralising solution. The swabs were connected to the cap and were used under aseptic conditions on various surfaces in the laundry such as press bottom, lift conveyor belt, flatwork shelf, transport wagon, side wall in transport wagon, different textiles.

2.3.2. Assessment of control points

Each swab was evaluated for aerobic count, coliform count and *Escherichia coli* count by the following procedures: (1) aerobic count: 1 mL of the neutralising solution with the immerged swab was inoculated and spread onto the Petrifilm aerobic count plate and incubated at 37 °C for 24 hours, followed by colony counting; (2) coliform/*E. coli* count: 1 mL of the neutralising solution with the immerged swab was inoculated and spread onto the Petrifilm coliform/*E. coli* count plate and incubated at 37 °C for 48 hours. The colonies of coliform bacteria appeared red coloured and a glucuronidase indicator formed a blue precipitate around any *E. coli* colonies present.

3. Results and discussion

The results of the sanitary microbiological assessment of six laundries in Slovenia that wash hospital textiles are shown in Tab.4. Tab.5 contains the results of the sanitary microbiological assessment of five Slovenian laundries that wash textiles from the food-processing industry. Tab.6 contains the results for the assessment of two laundries in Denmark that wash hospital textiles and in Tab.7 the assessment of five laundries in Norway that wash textiles from the food-processing industry are listed.

3.1. Hygiene level of the laundries and their textiles in Slovenia

Bioindicators: It was obvious from the results (Tab.4 and Tab.5) that the laundering procedures F, H and K did not have a sufficient disinfection effect, since the bioindicator bacteria *Enterococcus faecium* survived. In the laundering procedures, F and K *Staphylococcus aureus* survived, thus indicating an even less sufficient disinfection effect. All the procedures needed to be optimized to achieve an adequate disinfection effect.

Surface sampling: The surface sampling showed that the most common found microorganisms on the textiles were typical skin bacteria, such as coagulase negative staphylococci, *Micrococcus sp.* and *Corynebacterium sp*., thus confirming the overall unprofessional handling of cleaned textiles (sorting, ironing, folding and packing). *Bacillus sp.* and saprophytic Gram negative rods were also commonly found and indicated insufficient cleaning and disinfecting measures. Certain pathogen bacteria were also found, such as *Enterococcus sp* (storage shelves in laundry C, ironed and folded textiles in laundry J), *Pseudomonas aeruginosa* (technical equipment in laundries E and F) and *Staphylococcus aureus* (storage shelf in laundry J). In 2 out of 6 laundries for hospital textiles (Tab.4), the tolerance value was exceeded for surface sampling of ironed and folded textiles, damp textiles and hand hygiene. All the six laundries for hospital textiles

Tab.3 Tolerance values used for the laundries washing textiles from the food processing industry in Norway

Control point	Textiles laundered in laundry (total aerobic count)		All textiles (coliform/E. coli count)
	From health sector and from food processing industry	Only from food processing industry	
Tap water/treated water	100 cfu/mL	100 cfu/mL	0 cfu/dm^2
Technical equipment	100 cfu/dm^2	100 cfu/dm^2	0 cfu/dm^2
Textiles	20 cfu/dm^2	50 cfu/dm^2	0 cfu/dm^2

Tab.4 Results for the hygienic evaluation of the laundries that wash hospital textiles in Slovenia

CP		A	B	C	D	E	F
Washing process (Bio-indicators)	growth	none	none	none	none	none	*E. faecium, S. aureus*
	evaluation	disinfection effect	disinfection effect	disinfection effect	disinfection effect	disinfection effect	No disinfection effect
Surface sampling of ironed and folded textiles	growth	*Corynebacterium sp.*, CNS [a]	*Corynebacterium sp.*, *Micrococcus sp.*, CNS	CNS, SGNB, *Corynebacterium sp.*, *Bacillus sp.*	CNS, *Bacillus sp.*	*Bacillus sp.*	SGNB, *Corynebacterium sp.*, *Bacillus sp.*
	evaluation	< 20 cfu/dm^2 in all 10 samples	> 20 cfu/dm^2 in 1 out of 10 samples	> 20 cfu/dm^2 in 6 out of 10 samples	< 20 cfu/dm^2 in all 10 samples	< 20 cfu/dm^2 in all 10 samples	> 20 cfu/dm^2 in 2 out of 10 samples
Damp textiles	growth	CNS	CNS	CNS	*Corynebacterium sp.*	CNS	*Corynebacterium sp.*, NFGNB
	evaluation	< 30 cfu/dm^2 in both samples	< 30 cfu/dm^2 in both samples	> 30 cfu/dm^2 in 1 out of 2 samples	< 30 cfu/dm^2 in both samples	< 30 cfu/dm^2 in both samples	> 30 cfu/dm^2 in both samples
Tap water	growth	MAM [b]	MAM	MAM	MAM	MAM	MAM
	evaluation	< 10 cfu/mL at both incubation temperatures	< 10 cfu/mL at both incubation temperatures	< 100 cfu/mL at both incubation temperatures	< 10 cfu/mL at both incubation temperatures	< 10 cfu/mL at both incubation temperatures	< 10 cfu/mL at both incubation temperatures
Softened water	growth	MAM	MAM	MAM	MAM	MAM, *Bacillus sp.*	MAM
	evaluation	< 100 cfu/mL at both incubation temperatures	< 10 cfu/mL at both incubation temperatures	< 100 cfu/mL at both incubation temperatures	< 10 cfu/mL at both incubation temperatures	< 10 cfu/mL at both incubation temperatures	< 10 cfu/mL at both incubation temperatures
Rinsing water	growth	MAM, *Enterobacteriaceae*	MAM	CNS, yeasts, *Bacillus sp.*	*Enterobacteriaceae, Pseudomonas aeruginosa*	*Enterobacteriaceae, Pseudomonas aeruginosa, Bacillus sp.*	*Pseudomonas aeruginosa*
	evaluation	< 100 cfu/mL at both incubation temperatures	< 100 cfu/mL at both incubation temperatures	> 100 cfu/mL at 1 out of 2 incubation temperatures	> 100 cfu/mL at 1 out of 2 incubation temperatures	< 100 cfu/mL at both incubation temperatures	> 100 cfu/mL at both incubation temperatures
Technical equipment	growth	SGNB [c], *Corynebacterium sp.*	*Micrococcus sp.*, NFGNB [d] ,moulds	CNS, SGNB, *Corynebacterium sp.*, *Bacillus sp.*	NFGNB, CNS	*Corynebacterium sp.*, *Pseudomonas aeruginosa,* moulds	*Pseudomonas aeruginosa, Bacillus sp.*, *Corynebacterium sp.*, SGNB, NFGNB
	evaluation	> 100 cfu/dm^2 in 2 out of 5 samples	> 100 cfu/dm^2 in 1 out of 5 samples	> 100 cfu/dm^2 in all 5 samples	> 100 cfu/dm^2 in 3 out of 5 samples	> 100 cfu/dm^2 in 2 out of 5 samples	> 100 cfu/dm^2 in 2 out of 5 samples
Storage shelves/ transport	growth	*Bacillus sp.*, *Corynebacterium sp.*, CNS	*Corynebacterium sp.*, CNS	CNS, SGNB, *Enterococcus sp.*	*Bacillus sp.*	*Corynebacterium sp.*, *Bacillus sp.*, moulds	*Bacillus sp.*, CNS
	evaluation	< 100 cfu/dm^2 in all 4 samples	< 100 cfu/dm^2 in all 4 samples	> 100 cfu/dm^2 in 3 out of 4 samples	< 100 cfu/dm^2 in all 4 samples	< 100 cfu/dm^2 in all 4 samples	> 100 cfu/dm^2 in 2 out of 4 samples
Hand hygiene	growth	*Bacillus sp.*, *Corynebacterium sp.*, CNS	CNS	CNS	CNS	CNS	*Micrococcus sp.*, CNS
	evaluation	> 100 cfu/dm^2 in all 3 samples	< 100 cfu/dm^2 in all 3 samples	> 100 cfu/dm^2 in all 3 samples	< 100 cfu/dm^2 in all 3 samples	< 100 cfu/dm^2 in all 3 samples	> 100 cfu/dm^2 in all 3 samples

[a] CNS: coagulase negative staphylococci, [b] MAM: mesophylic, autochthonic microorganisms, [c] SGNB: saprophytic Gram negative bacilli, [d] NFGNB: non-fermentative Gram negative bacilli

Tab.5 Results for the hygienic evaluation of the laundries that wash textiles from the food processing industry in Slovenia

CP		G	H	I	J	K
Washing process (Bio indicators)	growth	none	*Enterococcus faecium*	none	none	*E. faecium, S. aureus*
	evaluation	disinfection effect	No disinfection effect	disinfection effect	disinfection effect	No disinfection effect
Surface sampling of ironed and folded textiles	growth	CNS [a]	*Bacillus sp.*, CNS, *Corynebacterium sp.*	CNS, *Bacillus sp.*	*Micrococcus sp., Enterococcus sp., CNS,* mould	*Corynebacterium sp., Bacillus sp.*, CNS, SGNB
	evaluation	< 50 cfu/dm^2 in all 10 samples	> 50 cfu/dm^2 in 2 out of 10 samples	< 50 cfu/dm^2 in all 10 samples	> 50 cfu/dm^2 in 2 out of 10 samples	> 50 cfu/dm^2 in 2 out of 10 samples
Damp textiles	growth	CNS	SGNB [c]	CNS	CNS	SGNB, *Corynebacterium sp.*
	evaluation	< 100 cfu/dm^2 in both samples	> 100 cfu/dm^2 in 1 out of 2 samples	< 100 cfu/dm^2 in both samples	< 100 cfu/dm^2 in both samples	< 100 cfu/dm^2 in both samples
Tap water	growth	MAM [b]	MAM	MAM, *Bacillus sp.*	MAM	MAM
	evaluation	< 10 cfu/mL at both incubation temperatures	< 100 cfu/mL at both incubation temperatures	< 10 cfu/mL at both incubation temperatures	< 100 cfu/mL at both incubation temperatures	< 100 cfu/mL at both incubation temperatures
Softened water	growth	MAM [b]	MAM, *Bacillus sp.*	MAM	MAM, CNS, *Enterobacteriaceae, Bacillus sp.*	MAM
	evaluation	< 10 cfu/mL at both incubation temperatures	> 100 cfu/mL at 1 incubation temperature	< 10 cfu/mL at both incubation temperatures	> 100 cfu/mL at both incubation temperatures	< 100 cfu/mL at both incubation temperatures
Rinsing water	growth	CNS	*Bacillus sp., Enterobacteriaceae, Pseudomonas aeruginosa*	*Bacillus sp., Pseudomonas aeruginosa*	*Bacillus sp.*	*Pseudomonas aeruginosa*
	evaluation	< 100 cfu/mL at both incubation temperatures	> 300 cfu/mL at both incubation temperatures	< 100 cfu/mL at both incubation temperatures	< 100 cfu/mL at both incubation temperatures	> 300 cfu/mL at both incubation temperatures
Technical equipment	growth	CNS, *Micrococcus sp.*	SGNB, *Corynebacterium sp.*	*Corynebacterium sp., Micrococcus sp.,* mould	*Corynebacterium sp.*, CNS	*Pseudomonas aeruginosa,* SNB, CNS, *Bacillus sp.*
	evaluation	> 100 cfu/dm^2 in 2 out of 5 samples	> 100 cfu/dm^2 in 3 out of 5 samples	< 100 cfu/dm^2 in all 5 samples	< 100 cfu/dm^2 in all 5 samples	> 100 cfu/dm^2 in 3 out of 5 samples
Storage shelves/ transport	growth	*Corynebacterium sp., Micrococcus sp.*	SGNB, *Corynebacterium sp.*	*Corynebacterium sp., Bacillus sp.,* mould	CNS, *Bacillus sp., Corynebacterium sp., Staphylococcus aureus*	CNS, *Bacillus sp.*
	evaluation	< 100 cfu/dm^2 in all 4 samples	> 100 cfu/dm^2 in 1 out of 4 samples	< 100 cfu/dm^2 in all 4 samples	> 100 cfu/dm^2 in 2 out of 4 samples	> 100 cfu/dm^2 in 3 out of 5 samples
Hand hygiene	growth	CNS, *Corynebacterium sp.*	CNS, *Corynebacterium sp.*	CNS	CNS	CNS, *Micrococcus sp., Corynebacterium sp.*
	evaluation	< 100 cfu/dm^2 in all 3 samples	> 100 cfu/dm^2 in 2 out of 3 samples	< 100 cfu/dm^2 in all 3 samples	> 100 cfu/dm^2 in all 3 samples	> 100 cfu/dm^2 in all 3 samples

[a] CNS: coagulase negative staphylococci

[b] MAM: mesophylic, autochthonic microorganisms

[c] SGNB: saprophytic Gram negative bacilli

exceeded the tolerance values for technical equipment, thus indicating that the overall hygiene in the laundries was not adequate. The tolerance limit according to the RAL-GZ 992/3 for surface sampling was exceeded at all control points of the laundries for textiles from the food-processing industry (Tab.5). In 3 out of 5 of these laundries, the tolerance values was exceeded for ironed and folded textiles, technical equipment, storage selves and transport vehicles and hand hygiene. It was found that the regular training and education of workers was the most important element for implementing an appropriate hygiene level in the procedures for handling clean and disinfected textiles after washing (sorting, ironing, folding packing) and that the basic hygiene demand was a disinfecting laundering procedure [4].

Water quality: The microbiological assessment of the water quality in the laundry showed that the initial waters (tap waters) reached the demanded hygiene level and that contamination occurred at subsequent phases. The hygiene level of the softened water was exceeded in the laundries H and J, whilst the hygiene level of the rinsing water was exceeded in the laundries C, D, F, H and K, thus confirming an inappropriate disinfection effect of laundering. *Pseudomonas aeruginosa*, an autochthonic water microorganism, was found in the rinsing waters of the laundries D, E, F, H and K. The representatives of the family *Enterobacteriaceae* were found in the rinsing water of the laundry A as well as in the laundries H and J in the rinsing water and softened water respectively. Since the tolerance values for the softened water were exceeded in the laundry D, thus confirming the contamination of the ion exchanger, it needed to be replaced [10].

Overall hygiene results: The overall worst results for laundered hospital textiles (Tab.4) were found in the laundry F, since both limit values according to the regulations of the Robert-Koch Institute were exceeded. The investigated laundering procedure did not have a disinfection effect against the indicator bacteria and the limit value for the ironed and folded textiles were exceeded. The laundry C also exhibited an insufficient hygiene level, since 6 control points exceeded the tolerance values (all control points except tap water, softened water and bioindicator survival). The laundries B and E exhibited the best results for hospital textiles, since only one control point was exceeded (technical equipment). In the laundries A and D, the tolerance values for two control points were exceeded. The overall worst results for textiles from the food-processing industry (Tab.5) were found in the laundry H, since the tolerance values for all the control points except tap water were exceeded. Only the laundry I did not have any results exceeding tolerance values. The second worst results for textiles from the food-processing industry were noted in the laundry K, since 5 out of 9 control points were exceeded. It was also obvious that both the laundries H and K did not have disinfection laundering procedures, since at least one bioindicator survived and the hygiene level of the rinsing waters exceeded tolerance values. The results confirmed that the disinfection effect of the laundering procedure was most important in preventing the dissemination of microorganisms in the clean area of the laundry, where all further work is done (sorting, ironing, folding and packing). It was also obvious that the laundries with inappropriate laundering procedures usually also had inappropriate cleaning and disinfecting measures of all technical equipment, storage shelves, transport vehicles and hand hygiene .On the other hand, it was obvious from the results of the laundries B, E and I that it was possible to implement cleaning and disinfecting measures which offered better hygiene level within the tolerance values in order to get clean and disinfected textiles for reuse [2, 4].

3.2. Hygiene level of the hospital textiles in Denmark

The results for the laundry evaluations in Denmark (tab.6) show that

Tab.6 Results for the evaluation of the laundries that wash hospital textiles in Denmark

Laundry	Category	Points	
		TPC[1]	E[2]
A	Sheet	15	15
	Bed cover	15	15
	Pillow case	15	15
	Pyjamas	15	15
	Doctor's uniform	15	15
	Sum	**75**	**75**
		Total points	**150**
B	Sheet	15	15
	Under clothe	15	15
	Pillow case	15	15
	Pyjamas	15	-10
	Doctor's uniform	0	15
	Sum	**60**	**50**
		Total points	**110**

[1] TPC: total plate count

[2] E: count of enterobacteria

Tab.7 Results for the evaluation of the laundries that wash textiles from the food processing industry in Norway

CP		A	B	C	D	E
Tap washing water	Aerobic count	No growth	12 cfu/mL	–	No growth	No growth
	Coliform count	No growth	No growth	–	No growth	No growth
	E. coli count	No growth	No growth	–	No growth	No growth
Treated washing water	Aerobic count	–	–	600 cfu/mL	–	–
	Coliform count	–	–	20 cfu/mL	–	–
	E. coli count	–	–	No growth	–	–
Press bottom	Aerobic count	>300 cfu/dm^2	–	No growth	300 cfu/dm^2	>300 cfu/dm^2
	Coliform count	100 cfu/dm^2	–	No growth	No growth	100-200 cfu/dm^2
	E. coli count	No growth	–	No growth	No growth	No growth
Lift conveyor belt	Aerobic count	0-100 cfu/dm^2	–	–	–	–
	Coliform count	No growth	–	–	–	–
	E. coli count	No growth	–	–	–	–
Flatwork shelf	Aerobic count	No growth	–	–	–	–
	Coliform count	No growth	–	–	–	–
	E. coli count	No growth	–	–	–	–
Transport wagon	Aerobic count	No growth	–	–	–	–
	Coliform count	No growth	–	–	–	–
	E. coli count	No growth	–	–	–	–
Side wall in transport vehicle	Aerobic count	0-100 cfu/dm^2	–	–	–	–
	Coliform count	No growth	–	–	–	–
	E. coli count	No growth	–	–	–	–
Textiles	–	quilt cover	quilt cover	quilt cover	quilt cover	quilt cover
	Aerobic count	0-100 cfu/dm^2	No growth	No growth	No growth	No growth
	Coliform count	No growth	No growth	No growth	No growth	No growth
	E. coli count	No growth	No growth	No growth	No growth	No growth
Textiles	–	terry cloth	sheet	Pillow case	Patient wear	workwear
	Aerobic count	>300 cfu/dm^2	No growth	No growth	No growth	>300 cfu/dm^2
	Coliform count	No growth	No growth	No growth	No growth	No growth
	E. coli count	No growth	No growth	No growth	No growth	No growth
Textiles	–	workwear	–	–	–	–
	Aerobic count	100-200 cfu/dm^2	–	–	–	–
	Coliform count	No growth	–	–	–	–
	E. coli count	No growth	–	–	–	–

the investigated hospital textiles in laundry A showed excellent results, since all the points were achieved, meaning that no more than 2 cfu/ cm^2 of the total bacterial count were found on any of the tested textiles and no representatives of the family *Enterobacteriaceae* were found. On the other hand, the results in the laundry B reached the level 3 (neutral), since a representative of the family *Enterobacteriaceae* was found on one tested textile (patient's pyjamas) and the total bacteria count was higher than 2 cfu/ cm^2 on the tested doctor's uniform. However, these results do not clearly say whether the contamination occurred after laundering or if the laundering procedure it self had no adequate disinfection effect.

3.3. Hygiene level of the laundries and their textiles from the food processing industry in Norway

The results in Tab.7 show that only the laundry B did not exceed any tolerance limit. On the other hand, several control points in the laundries A, C and E were exceeded and one control point was exceeded in the laundry D (press bottom). In the laundry C, the aerobic count and the coliform count for treated water was exceeded, therefore the laundry should implement some disinfection measures of the treated water before using it in the laundering procedure. The rest of the results show that the laundering procedures were able to eliminate, at the moment, the bioburdon of the treated water, however if the bioburdon of the treated water increased, this would not be the case anymore. The laundries A, D and E had a problem with the press bottom, since the aerobic count was exceeded in all three laundries and the coliform count of the press bottom was also exceeded in the laundries A and E. It is necessary for these laundries to implement rigorous cleaning and disinfecting measures of the press. It was also noted that new continuous batch washers gave rise to problems in press and press water results in the laundries that did not previously have any problems with hygiene. The problem was perhaps due to the low water consumption and the contamination of the rinsing zone. In the laundries A and E, the aerobic count on the tested textiles was also exceeded, thus indicating that the further handling of textiles (sorting, ironing, folding etc) was not performed in a professional manner. The workers should be instructed on improving cleaning and disinfecting measures of their hands and all the equipment that comes into contact with the textiles.

4. Conclusions

The review of the hygiene level of the laundries in Slovenia, Denmark and Norway shows that, although all laundries did not achieve the demanded levels of hygiene, it is possible to reach them. The first factor is optimizing the laundering procedure to have an appropriate disinfection effect, being at the same time at an efficient quality level. Additionally, it is also very important for all the workers, especially in the clean area of the laundry, to apply regular cleaning and disinfecting measures in order to prevent the recontamination of cleaned textiles in the process of handling textiles after washing and drying (sorting, ironing, folding and packing). This research has also shown that it is not important which system is used for implementing these measures, as long as the measures are performed regularly and by all the personnel, meaning a high level of commitment and involvement is required by the management and by all workers.

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