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AN INVESTIGATION OF DOMESTIC LAUNDRY IN EUROPE - HABITS, HYGIENE AND TECHNICAL PERFORMANCE

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The categories are:

- Laundering practices
- Attitudes
- Detergents used
- Temperature used and the frequency of doing laundry in the households.

Links between these findings that may be of interest in the scope of this research are pinpointed and discussed.
Spain is the country, which definitely shows the most different patterns in this investigation. This pertains to both performance and hygiene, as well as to laundry habits.
A test method for establishing the hygiene quality of washing laundry under real life conditions has been developed. The method has proven repeatability and validity. Further fine-tuning is still needed for the selection of laundry samples and the sampling itself.

Keywords

Laundry, habits, hygiene, washing performance

An investigation of domestic laundry in Europe – Habits, hygiene and technical performance

by

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Preface

In order to promote the interests of the consumer within the framework of article 2 of EU Parliament decision no 283/1999/EU, a consumer policy programme has been developed. Each year the Commission calls for project proposals to make it possible to fulfil the obligations in the programme. Some of the task fields are highlighted specially. For 2001 one of these was "promotion of consumer interests and education of consumers". The motivation for our application was related to the following:

> To give everyone, including consumer representatives, the possibility to have updated results and neutral information. This will in our view be of major importance since representation by industry in standardisation work is strong, and knowledge about the domestic laundry habits of today has its origin in investigations performed by the industry. The results from the project may also contribute to consumer protection in the sense that they can help to prevent policy measures from resulting in a deterioration of consumers' interests.

In addition to the direct results achieved, the project has also made it possible to extend knowledge and communication between research institutions and consumer organisations in 4 different countries: Spain, Greece, the Netherlands and Norway, represented by Edocusa (OCU), the General Consumers Federation of Greece (INKA), Wageningen University dept. Consumer Technology & Product Use (WUR) and the National Institute for Consumer Research (SIFO), respectively.

We would like to thank all contributors in the four countries for their spirit of co-operation and their efforts to make the project successful. First of all: special thanks to Anna Risnes who had the idea for the project, organised the project team and wrote the application, then left for an even more exciting responsibility – a new baby just as the project started.

In the project team, special recognition goes to Carja Butijn and Anneke Engelbertink in the Netherlands, Vassilis Georgakopoulos and Haris Kouris in

Greece, Silvia Arquiaga, Amaya Apesteguia and Antonio De la Torres in Spain and Anne Sofie Bjørnlund, Tone K. Bergh, Line Sommerfeldt and Torill Næss Engen at SIFO. Although they are not listed directly among the authors, their contributions have been invaluable in making this project possible.

Oslo, March 2003
National Institute for Consumer Research

Contents

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- Laundering practices
- Attitudes
- Detergents used
- Temperature used and the frequency of doing laundry in the households.

Links between these findings that may be of interest in the scope of this research are pinpointed and discussed.

First, some overall remarks can be made. For instance, almost all the households dealt with in this study have a washing machine and use this as their main washing method. Further, the answers from the survey show that doing laundry still seems to be a "female thing"- especially in Greece. However, we will not go further into any analysis of this question.

Spain is the country, which definitely shows the most different patterns in this investigation. This pertains to both performance and hygiene, as well as to laundry habits.

A test method for establishing the hygiene quality of washing laundry under real life conditions has been developed. The method has proven repeatability and validity. Further fine-tuning is still needed for the selection of laundry samples and the sampling itself.

Laundering practices

In this section the findings related to common practice are compiled. The survey in chapter 2 indicates that the mean wash temperature in Norway and Greece does not appear to be as different as was found in a previous investigation in the SAVE II project. [8].

The survey shows that consumers in Greece and especially Norway tend to change clothes less often, but to compensate for this, they wash at higher temperatures when they do their laundry. This practice could lead to a higher level of laundering hygiene because of the fact that higher wash temperatures yield better germ reduction.

Apparently the middle-age generation, regardless of country, has the most remedies to be used for laundry in the house. This could reflect several things. One postulate is that members of this generation (36-55 years of age) have experienced a huge growth in the number of possible remedies. They could see this as an opportunity to use less time and effort on their laundry, and it could also be an expression of great faith in "the wonders of chemistry". Further, they have the financial means that allows them simply to discard remedies they do not like after having tried them once, or in worst case to buy new clothes if the remedy tried did not work quite as anticipated. Another explanation for this collection of remedies could be the fact that people within this age group are responsible for a family. There are simply more people in the household, all with different needs and preferences.

Another interesting age-related finding is the fact that there seem to be more households, which use bleaching agents among the youngest respondents in Greece and the Netherlands, while these remedies are more widely used among middle-aged households in Norway and Spain. The use of more bleaching agents by younger people implies that future hygiene may be safeguarded, as bleach improves the level of hygiene. In this respect we could conclude that the 'new' generations in Greece and the Netherlands have a more hygienic laundering practice. Contradicting this is the fact that young people also tend to be a group concerned about the environmental effects of remedies they use. Extensive use of bleaching agents is not very environmentally friendly. Young people are not especially vulnerable to diseases caused by poor laundry hygiene, and should for this reason not be expected to be so focused on hygiene issues that they rank them above environmental aspects.

The use of softeners is an issue that is being debated in several fora. Both environmental and allergenic effects are part of this discussion. It should be mentioned that the use of softeners and possible impacts of such use on the results (either the washing effects or the hygienic quality) has not been taken into account in this study.

When washing with the most common domestic laundering processes used in four European countries, the hygienic quality measured after the washing process is more or less comparable for Greece, Norway and the Netherlands. The Spanish washing processes, by contrast, although low temperatures (15 and 30 °C) are used, show a higher reduction in the level of micro-organisms after washing. This effect is probably caused by an additional rinse in the washing programme. This effect might represent an interesting finding from the point of view of the environment. Demanding more water is a lesser burden than washing at high(er) temperatures.

Attitudes

Some of the findings from the survey suggest that respondents in Spain are more concerned about the appearance of clothes than the hygiene aspects. They also claim to be concerned about the environment, but their frequent change of clothes followed by more frequent washing contradicts this. On the other hand, washing at low temperatures is a step in the right direction regarding the environment.

A general remark regarding attitudes is that there seems to be a high level of conformity (compared to general experience from similar types of surveys) between the attitudes expressed by respondents and what they actually do. One deviation from this, however, is from some of the Spanish respondents where there seems to be some disharmony between what they think they do (positive effect on the environment when using low temperatures in the washing process) and what they actually do (changing clothes very often, and thus running the risk of subjecting nature to environmental impacts more often).

There is relatively little use of special colour detergents in Greece. An interesting point related to this is that according to the survey, consumers in Greece do not think that modern detergents wash white “anyway”. The Greek consumer wants detergents with bleaching agents or remedies with that effect.

Do younger people tend to wash clothes more often than those who are older? We do not have a conclusive answer to this question. What the results show is that younger people change clothes considerably more often than the older generation. The difference is less, however, when compared to middle-aged people (36-55 years). The question is interesting nonetheless and the idea was to check out the possible consequences based on an assumption that new textiles are more widely used among young people. Those textiles are very often labelled with low washing temperatures (whether this is necessary or not) and with advice to wash garments separately. This alone will most certainly lead to more frequent washing. Reinforcing this is the fact that amongst the younger generation is it often part of the social code to appear clean and "newly washed".

Detergents

One of the original ideas for the project was to investigate a possible influence on the results of the content of the detergents. However, this idea had to be abandoned at an early stage due to lack of information. Even though that has not been part of these investigations, the fact still remains that the composition of detergents is of vital influence.

The results show that Spain has better results with traditional detergents (listed with the code "B" in this project) at 30°C for both hygiene and washing efficiency, when compared to the other types of detergent tested. The good hygiene effect of the Spanish laundering process appears to be due to the fact that the detergent foams more strongly than the other detergents. The explanation could be that in some machines with foam detectors an extra rinse is automatically added to reduce the foam. This extra rinse then adds more water. Additional investigations (see chapter 4) show that more rinse results in substantially better laundry hygiene. This additional rinse is, however, not a full explanation for the better washing efficiency.

Greece and Spain seem to have the detergents for white textiles with highest wash performance. Both countries are known to use traditional detergents most commonly. Greece has very good results in wash performance using the compact detergent. The traditional detergent is more widely used but does not have the same wash performance as the compact detergent. This contradicts the pattern we see in Spain, where the results clearly demonstrate that the detergents that are most used also show the highest wash performance.

The most common wash processes for white textiles in Spain and Norway (respectively) seem to have about the same average value on wash performance even though the Norwegian detergent is tested using a higher wash temperature and lower water hardness. The Norwegian detergents seem to have a lower wash performance than we would expect when tested under the most common Norwegian conditions. This indicates that the Norwegian detergent is not properly adapted to the common Norwegian wash processes. Another possibility is that the dosage on the label is too low. We may conclude that Norwegians consume much more energy than the Spanish to gain the same wash performance for their white textiles.

All the liquid detergents we tested have a significantly lower wash performance than the compact detergents tested. In fact, the wash performance when using water alone is similar to using the Spanish liquid detergent. The dosage used for the Spanish detergent is quite high, and this may have caused the very bad results for this particular detergent. The poor results, combined with the extremely high foam level during testing, may indicate that a different programme with less mechanical action and less programme duration is more likely to be used for this detergent in Spain. The liquid detergents from the other countries are significantly better than using just water, but in terms of wash performance alone we would advise consumers to use other types of detergents. However, with regard to rinse performance, we find that the liquid detergents have high rinse efficiency compared to the other types of detergents. This is valuable information for people with allergic reactions from residual detergent after wash.

Temperature effects of the washing process

The investigations in this study indicate that the results from the washing performance test at different temperatures do not seem to be as differentiated (specially between Norway and Greece) as was found in a previous investigation done by the A.I.S.E [16].

From the research results of the hygienic study, there are strong indications that the hygiene quality of washed laundry when still wet is related to the washing temperature and the presence of bleaching agents. A general observation is that the result of washing processes at low temperatures (15 and 30°C) shows a rather low hygienic quality. Hardly any reduction in numbers of micro-organisms is achieved. This is confirmed by an additional test. Almost all micro-organisms were removed from the laundry samples by a 95°C programme using a detergent containing bleach.

One of the most interesting findings is that washing at low temperatures seems to spread micro-organisms among the different laundry items in a washing sample rather than removing them. Temperature and hardness of water both affect washing efficiency. Temperature alone is far more decisive than hardness alone. Together there might be a reinforcement of effects, but this must be analyzed further in order to reach a conclusive result.

1 Introduction

1.1 Laundry: historical and cross-cultural

How laundry should be done and why is a question that has evoked different answers throughout history and, as we shall see in the study, there are also differences between nations. In the 19^{th} century and the first part of the 20^{th} century, laundry was done using other methods and other remedies than today Sundt 1975[11], Løfgren 1979[12], Rasmussen 1977[14]. Farmers washed and changed before big events of life. Washing themselves and changing to freshly laundered clothes was like a purification process. The upper and middle classes, however, considered dirt dangerous and disgusting Frykman & Løfgren 1979[12]. In 1882 the bacillus that carries tuberculosis was discovered, and after this period one important aspect of laundering was the fight against *bacteria*. Dirt was bacteria and bacteria were dirt. From the scientific point of view, lower class people were not regarded as clean, and laundry was one way to rectify this. To a great extent cleanliness became a culture and an arena of discord among the classes, and the use of soap and water was seen as an indication of a civilized society Frykman & Løfgren 1979 [12]. During the first part of the 20^{th} century, major changes took place in the realm of laundry. As the hygienic aspect gained more support Maartmann 1998 [13], the amount of laundry increased considerably Klepp 2003 [15]. Knowledge of the ramifications and the technical aspects of laundry were to a much greater extent than previously institutionalised and formalised. This became evident in the emergence of courses and schools for housewives, as well as in the growth of the detergents industry. Advertising and information campaigns increasingly became the new arenas for knowledge on how to do laundry, compared to previously when this kind of information was learned in a personal and domestic context.

The fight against dirt took place more or less at the same time in the different countries in Europe. War and peace and the fluctuations in the economy meant varying emphasis on this front, as well as varying progress in the field. From 1970 hygiene in Europe has reached the status of what Bourdieu [10] calls a doxa, i.e. it is no longer an issue but something everyone unconsciously endorses by acting according to the existing convention Bourdieu [10]. This could indicate that laundry is something people do without necessarily thinking too much about the hygienic aspects. Since the beginning of the 1970s the time spent doing ordinary housework has been reduced considerably. Even though the differences due to cultural tradition and economic development will show some variation among the countries of Europe, there is reason to believe that the trend has been more or less the same everywhere.

1.2 Why study laundry?

The many elements involved in the laundering process indicate that the study of laundry is important. How we handle our laundry influences many aspects of society, both today and in the future. The effects on hygiene and health have already been mentioned; how we perceive and present ourselves in a social context is another consideration. Another very important element is the consumption of energy, water and chemical detergents. In recent years the environmental impact of human actions has been in constant focus, and many efforts have been taken to restore a more sustainable development. The means used are eco-labels and energy labels, in addition to legislation (for instance regulating the content of detergents).

The object of this study is to examine the present laundry habits, cleaning quality and the related hygiene situation in four European countries: Greece, the Netherlands, Norway and Spain. The countries involved were selected because they have very different laundry patterns. A survey from A.I.S.E. [16] shows that consumers in Spain use the lowest mean washing temperature (33°C) and mainly traditional detergents. In the Netherlands, the mean washing temperature is about the same as the mean European temperature (49°C) and the detergent used is mainly the compact type. Norway has the second highest mean washing temperature (53°C) and uses mostly a compact type of detergent. The highest mean washing temperature is in Greece (60°C), where detergents of the traditional type are mainly used.

This project is divided into three main parts: a survey of laundry habits (chapter 2), assessment of laundry performance (chapter 3) and assessment of hygienic quality (chapter 4). The last two chapters contain remarks regarding environmental protection, consumer care and safety related to hygiene and some guidelines for standardisation bodies (chapter 5). In chapter 6 suggestions are made for future work in this field.

2 Assessment of the consumer laundry habits - a quantitative survey

Ragnhild Brusdal

2.1 Data collection and data material

2.1.1 The data

Four countries participated in the survey, all selected for different reasons as described earlier. A draft questionnaire was drawn up in Norway and discussed with the other countries involved, and the necessary corrections and changes were made. The questionnaire was written in English and later translated to the local languages in collaboration between SIFO and the affiliates in each country.

In each country a sample of approximately 1000 persons was selected from the population. The data was collected in February and March 2002. In Greece, the Netherlands and Norway data collection was done by telephone interviews (CATI). In Norway, the Norwegian Gallup was responsible for the data collection, and in Greece and the Netherlands the surveys were run parallel with Gallup Partner Institute Taylor Nelson Sofres. In Spain the EDOCUSA did the data collection by conducting direct interviews in the streets, shopping malls and other crowded areas of 22 representative Spanish cities. When the questionnaires had been filled out they were sent to Norway, where Gallup did the data processing.

This survey investigates how people handle their laundry. To obtain exact knowledge we needed to question the person in charge of all or most of the laundry in the household. In all of the countries, when approaching a person and requesting an interview, we had to ask if he or she was the person in charge of the laundry in the household. This means that the samples are representative *for the person in charge of the laundry* in the different countries. There is one small difference, however: the Spanish sample was selected in a different way, by randomly choosing people in the streets to participate. However, since the survey does not deal with a sensitive topic, we would not expect that a higher proportion refused to participate in Spain. On the other hand, it is important to have in mind the different sampling methods when analysing the data.

2.1.2 Who does the laundry?

Our point of departure was that we wanted information from the person in charge of the laundry. When approaching a person, the interviewer was instructed to ask for "the person who is mainly responsible for the household laundry". Table 2.1 shows that laundry is primarily women's responsibility, especially in Greece. There are small differences between the other countries. In Norway we find the largest share of men who are mainly responsible for the laundry, 18 %, closely followed by Spain and the Netherlands with 15 and 14 %, respectively (see table 2.1).

Table 2-1 The person in the household mainly responsible for the laundry in the different countries. Per cent

	Greece (N=1000)	**Netherlands** (N=1001)	**Norway** (N=1008)	**Spain** (N=1001)
Male	4	14	18	15
Female	96	86	82	85

2.1.3 Different laundry habits?

Households differ in many ways, and we expect this to affect how much laundry needs to be done and how it is done. We have already seen that the person in charge of the laundry is usually female. We wanted to see if there were any differences between the generations. When we divided people into three age groups, the analysis reveals that there are relatively small differences between the countries when it comes to age.

If you are living by yourself it is most likely that you have to do your own laundry. Since our sample consists of the person in charge of the laundry, we should expect to find more men in the “single” categories. Our analysis confirms that there is a larger share of men in the “single” categories (single or previously married) than in the categories of married and cohabiting.

Laundry is gendered work; that is, if you are married or cohabitant it is most likely that the woman is in charge of the laundry. This pattern is most distinctive in Greece, where only 1 % of the married persons in charge of the laundry were male. At the opposite end of the scale we find the Norwegian respondents, where 12 % of the married persons in charge of the laundry were male.

How much time you spend and how you do your laundry might have something to do with the amount of laundry to be done, which in turn is related to how many persons there are in the household. Greek households tend to have the greatest number of people in them; 30 % consist of 4 persons, and 16 % of Greek households consist of 5 persons or more. On the opposite end we find that the Norwegian households are most likely to consist of only 1 or 2 persons.

2.2 Use of machines

Machines are meant to make work easier. Hence the more work you have to do, the more you can profit from using a machine. In all four countries the washing machine is standard equipment, and almost every household has its own (from 95 to 99 %).

A tumble dryer can also save time. You don’t have to hang up the clothes to dry, and afterwards less ironing is required. Further, it makes it possible to handle more laundry in a shorter time. Finally, the tumble dryer can be a good solution if you have a lot of laundry, but less space to dry it. However, the tumble dryer is not as common as the washing machine, and there are substantial differences between the countries. In the Netherlands the tumble dryer seems to be quite common; 71% of the households have one. In Norway a little less than half of the households have one (47%). In Greece it is very rare to find a household with a private tumble dryer (only 5%). In Spain owning a private tumble dryer is not as rare; every 4^{th} household owns one.

We found that the share of households having a tumble dryer increases with the number of persons in the household. This tendency is the same in all the countries except Greece, but here the percentage owning their own tumble dryer is very small.

When we turn to the hours spent on laundry, we discover that the Spanish respondents use more time than the respondents in the other countries. Why this is so is unclear. The Spanish respondents have the same share of households with their own washing machine, so this is not the reason. They have a smaller share of households with tumble dryers compared to the Netherlands and Norway, but not compared to Greece, so this is not the reason either. Another explanation could be that the Spanish respondents interpret the question differently and refer to the entire process when clothes are being washed, i.e. including the time when the washing machine is on. In the manual for the survey, working time was defined as "The time it takes until the clothes are hanging on the clothesline to dry or are put into a tumble dryer. That is, not ironing or putting clothes away".

Table 2-2 Average time spent on laundry in the different countries. Hours.

	Greece (N=1000)	Netherlands (N=1001)	Norway (N=1000)	Spain (N=958)
Average time	2.87	4.51	3.68	9.18

However, it is possible that the Spanish respondents do spend more time doing laundry. This could be because they wash their clothes and textiles more frequently, or they put fewer textiles in the washing machine. It is also possible that the Spanish respondents include the cycle of the washing machine in the answer, while the other respondents do not. With this in mind, we shall soon approach the subject of how the laundry is done, but first we shall investigate whether there are different attitudes towards laundry in the participating countries. These attitudes might also explain different patterns of doing domestic laundry.

2.3 Attitudes towards domestic laundry

They ways people do their laundry could be explained by different factors. Some of them are measurable facts, such as how much laundry you have, whether you get dirty doing your work or sports, what machines and other equipment you have at home etc. Others are less tangible; in each society there are norms and expectations as to what standards are acceptable and how different tasks should be done.

Ten statements regarding laundry habits were listed in the questionnaire, and the respondents were asked to what extent they agreed or disagreed with these. We adopted a scale ranging from 1 to 5, where 1 signified "fully disagree" and 5 signified "fully agree". The statements dealt with several topics:

1) Attitudes on how textiles are presented in a social context
2) Attitudes on the cleanness of textiles
3) Attitudes towards the laundry process and its impact.

These statements also address other aspects and could of course be interpreted in other ways, but for the present purpose we shall stick to these three themes.

2.3.1 Attitudes regarding textiles in a social context

Most clothes are public in the sense that when you are wearing them, anyone can see and smell them. We had three statements related to the public aspects of clothing:

- *Clothes should always smell as if newly washed*
- *It is embarrassing to wear clothes with a body odour*
- *Boiling is unnecessary as modern detergents keep clothes white anyway.*

Figure 2-1 shows that smell is not accepted in any of the countries[1]. Especially the Spanish respondents hold that clothes should not have a body odour, followed by the respondents from the Netherlands and Spain. The Norwegian respondents seem to be less concerned about smell.

The statement that clothes should smell as if newly washed is most strongly agreed with by the Greek respondents, followed by the Spanish respondents, while the respondents from the Netherlands and Norway seem to place less emphasis on this aspect.

The third statement refers to the appearance of textiles or garments: "You don't have to boil modern textiles to keep them white". In all of the countries the respondents agreed less with this statement. The Spanish respondents seem to have the most confidence in modern detergents and low temperatures, while the Greeks and Norwegians are the most sceptical.

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[1] In the following figures the different countries will be presented in alphabetical order, i.e., Greece, the Netherlands, Norway and Spain.

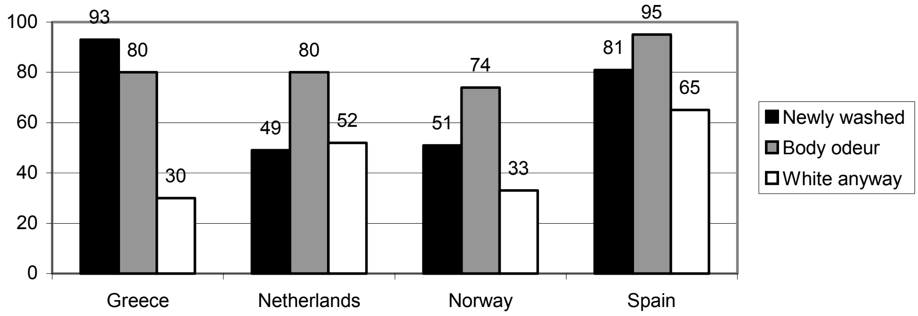

Figure 2-1. Percentage who fully agreed with different statements concerning how textiles are presented in a social context.

To summarise, the respondents in Greece and Spain were more concerned about how textiles present themselves in a social context than respondents in the Netherlands and Norway, and this is most prominent when it comes to smell. Almost everyone in the Spanish sample fully agreed that body odour is embarrassing, while only about half of the people in the Netherlands and Norway fully agreed that clothes should smell as if newly washed.

2.3.2 Attitudes on cleanness and hygiene

Clothes should look clean and not smell, but what about cleanness and hygiene? Earlier we mentioned that people have many reasons for doing their laundry the way they do. Laundering is a process performed to get textiles clean. Clothes with dirt and stains or residuals of detergent many constitute both aesthetic and health problems. But what is considered dirt and what is not differs from one culture to another. Laundering has also a hygienic aspect. Dirt can spread infectious disease, and soap residue in clothing can cause allergic reactions. We wanted to investigate whether people are concerned about hygiene when laundering. Two statements should give some indication of this:

- *Clothes hygiene is important to me*
- *Today's detergents are so good that clothes get clean even when washed at low temperatures*

Figure 2-1 (see previous section) shows that the Greek respondents agreed most with the statement that clothes should smell as if newly washed, while the respondents from Norway and the Netherlands were not equally concerned about this. The Spanish respondents were most concerned that body odour should not occur. In all of the countries, and especially between the Greek and the Norwegian respondents, there seems to be a strong feeling that textiles need to be boiled to be kept white. Is this related only to the appearance of the textiles, or are the respondents concerned about hygiene as well?

In all participating countries the respondents emphasise the importance of clothes hygiene (Figure 2-2). This attitude is strongest in Greece, followed by the Netherlands, Norway and finally Spain. This is in accordance with the responses as to whether it is necessary to boil textiles to keep them white. However, it should be noted that a large share of respondents in every country fully agrees that it is important to them that their clothes are hygienically clean.

When it comes to how to get clothes clean, we see that especially the respondents from the Netherlands and Spain seem to have a greater confidence in modern detergents. Whether this is justified or not will be examined later. The Norwegian respondents are less confident in the result when washing at low temperatures, closely followed by the Greek respondents. This is in accordance with their scepticism towards the statement that “Today’s detergents are so good that clothes get clean even when washed at low temperatures”.

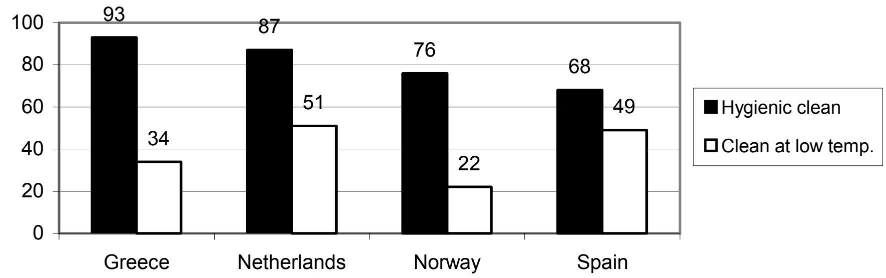

Figure 2-2. Share who fully agree with different statements concerning hygiene. Per cent.

2.3.3 Attitudes towards the laundry process and its impact

Our next step was to look for any differences in attitudes towards how laundry should be done as well as how it is actually done. This is important for many reasons; for instance, if there is a broad consensus that people wash too much or too often, it might be easier to change this. On the other hand, if the result of the laundering is not satisfactory, this may generate a negative environmental effect because of more frequent laundering, ruined clothes or increased use of additional laundry products (for instance stain remover and chlorine bleach). Five statements were presented describing attitudes towards the laundry process, related to clothing and to the environment:

- *People today generally wash their clothes too often*
- *Modern laundry habits are generally harmful to the environment*
- *I always examine washing instruction tags carefully*
- *Laundry wears out clothes more than actually wearing them does*
- *Hot water wears out clothes more than cold water does*

The number of statements makes it difficult to give a straightforward description. However, figure 2-3 shows that the Spanish respondents differ significantly from the others in regard to three of the statements: “Laundry wears out clothes more than wearing them does”, “Hot water wears out clothes more than cold water does”, and finally “Modern laundry habits are generally harmful to the environment”. This indicates that the Spanish respondents are more likely to perceive the technical aspects of laundering as harmful either to clothes or to the environment. The respondents in the other countries agree more or less at the same level, with the exception that a very small share of the Norwegian respondents feels that hot water wears out clothes.

Modern laundry habits do not seem to be related to the environment other than in Spain. Only a small share (about 25 % of the respondents in Greece, the Netherlands and Norway) fully agree with the statement that modern laundry habits are harmful to the environment. In response to the question of whether clothes are washed too often, half of the respondents in Spain and Greece fully agree with this statement, while fewer respondents in Norway and the Netherlands share this opinion. We shall have a closer look later as to whether practice varies on how laundry is done. One statement referred to whether wash instructions are examined. Figure 2-3 shows that a fairly large proportion, between 55 and 61 %, agreed with this statement in all of the countries.

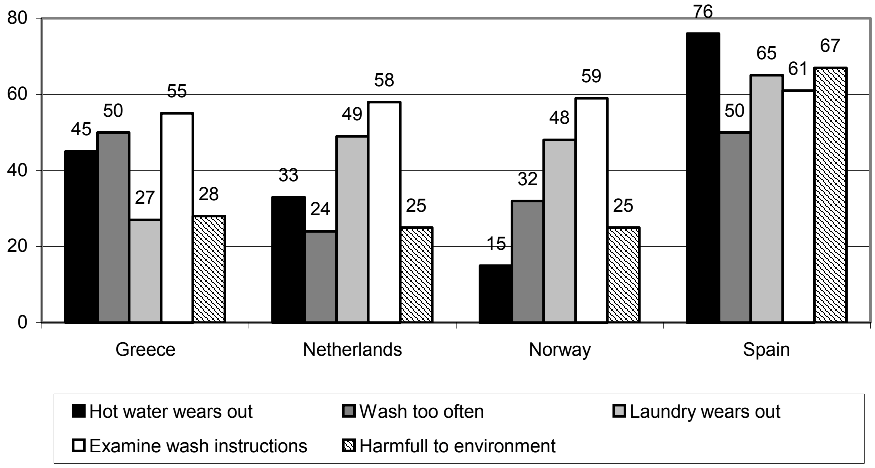

Figure 2-3. Attitudes towards the technical aspects of laundry.

To summarise, attitudes do differ somewhat from country to country, and the respondents from Spain seem to differ more from the respondents in the other countries. We shall now examine whether the respondents' laundry habits are in accordance with their attitudes.

2.4 How domestic laundry is done in different countries

The previous section showed that there are different attitudes towards laundry in the different countries. The next step is to consider the relationship between attitudes and how laundry is done. To elucidate this we posed several questions as to how households handle their laundry:

How often different textiles were washed
How the laundry is done (by machine, by hand or otherwise)
At what temperature the laundry is done
What detergents the household uses.

There are many types of textiles; some are made of robust materials, while others are more delicate. Some are worn close to the body and are associated with sweat and body odour, others not. In the questionnaire we have distinguished between 8 different textiles and their areas of application. Two of these are household textiles (bath towels and bed sheets), while the other six are garments of different materials that are worn more or less close to the body.

2.4.1 Bed sheets

Figure 2-4 shows that the Greek respondents change bed sheets most often and the Norwegian respondents most seldom. 22 % of the Greek respondents change bedclothes several times a week, compared to only 2 % of the Norwegian respondents. The figure also shows that the respondents from Greece, Spain and the Netherlands most commonly change bed sheets once a week, while in Norway it is most common to change them every second week.

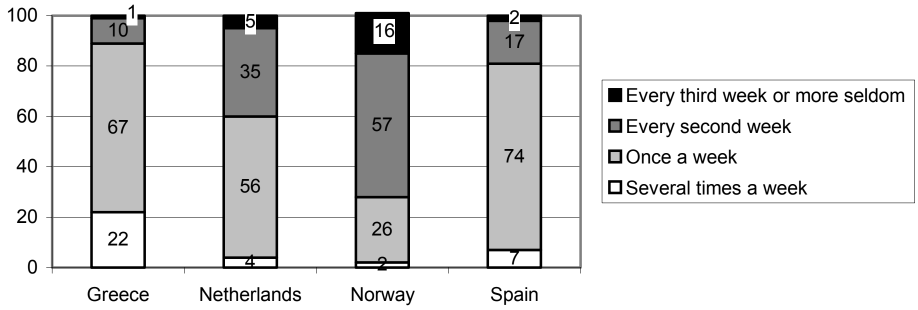

Figure 2-4. Frequency of changing bed sheets in different countries. Per cent.

Figure 2-5 shows that the respondents from Spain wash their bed sheets at much lower temperatures than respondents from the other countries (35 % stating that they use cold water, and 40 % using 30 °C). The Greek and Norwegian respondents wash their bed sheets at considerably higher temperatures. The most usual temperature among the Norwegian respondents is 60 °C, while 20 % of the respondents wash their bed sheets at 90 °C. This pattern is quite similar to the Greek respondents, where we find that a somewhat larger percentage wash their bed sheets at 70 °C and a smaller percentage at 60 °C. Boiling or washing at 90 °C are not so common, but about 20 % of the respondents in Norway and Greece do this. The temperature used by the respondents in the Netherlands is somewhere in the middle. A larger share wash their bed sheets at 40 °C than in the other countries, but 60 °C is the most usual temperature.

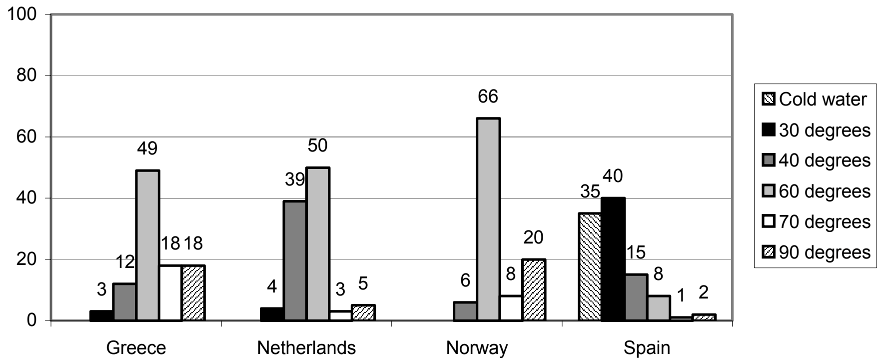

Figure 2-5. Survey of temperatures that bed sheets are washed at in different countries. Per cent.

2.4.2 Bath towels

While the respondents from Greece reported that they changed bed sheets most often, it is the respondents in the Netherlands who most frequently change bath towels. 61 % of them report that they use a bath towel only once before washing it. At the opposite end of the scale, only 19 % of the Spanish respondents report using a bath towel only once. In Spain it is most common to use bath towels 5 times or more. Many of the Norwegians and the Greeks also change their bath towels after a single use, but this is not as common as it appears to be in the Netherlands.

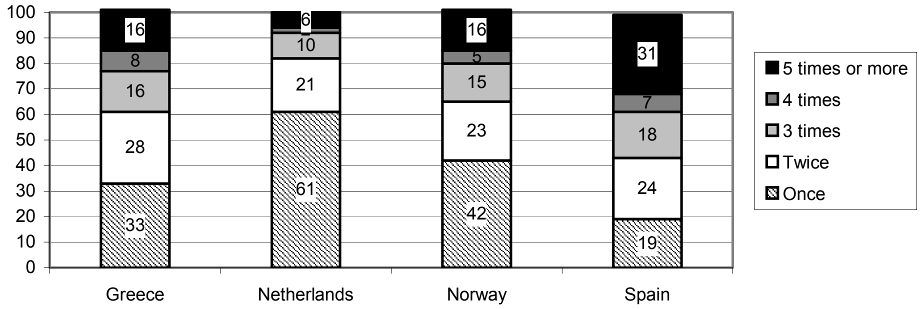

Figure 2-6. Number of times bath towels are used before laundering in different countries. Per cent.

The responses also showed that bath towels are washed at almost exactly the same temperatures as bed sheets (see figure 2-5). When it comes to the technical aspects of doing laundry, bath towels are mainly washed by machine in all of the countries, and the pattern is almost exactly the same as for bed sheets. These two household textiles seem to be washed more or less the same way in all countries.

2.4.3 Jeans

Even though we often think of jeans as blue jeans, they come in all colours, sizes and fabrics. Jeans are popular and may be used for leisure activities, social occasions and for work. It is not clear exactly what type of jeans each person in the survey is referring to. It should also be mentioned that not everybody has jeans, and especially not all of the women. Since the person in charge of the laundry is usually female, this could explain why 31 % of the Greek respondents find this question not relevant, followed by 18 % in Spain, 17 % in the Netherlands and 4 % in Norway. Jeans seem to be a more masculine garment in Greece, but to be used more by both sexes in Norway.

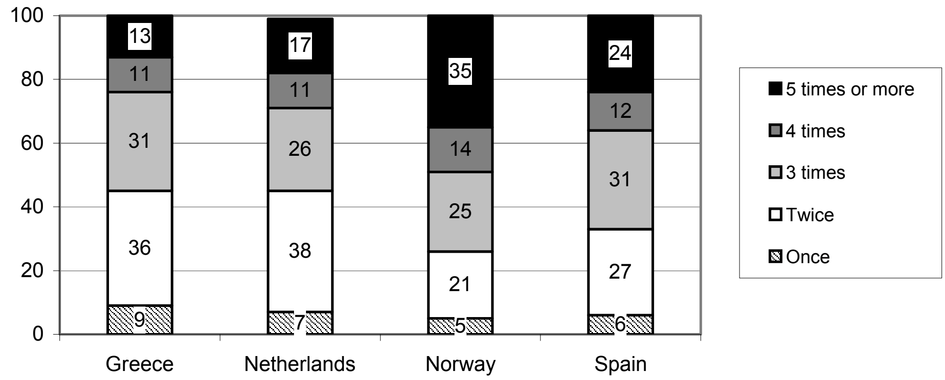

Figure 2-7. Number of times jeans are worn before laundering in different countries. Per cent. (N=3220)

The respondents in Greece and the Netherlands wash their jeans more often than the respondents in Spain and Norway. In Greece and the Netherlands jeans are most commonly washed after having been used twice, while among the Spanish respondents jeans are most commonly washed after 3 times use. Norwegians use them several times more; the most common response is that jeans are washed after being used 5 times or more.

Even though almost all the respondents wash their jeans in a washing machine, the temperature used differs considerably. Again the Spanish respondents seem to be most inclined to use cold water. 47 % say they wash their jeans in cold water. The Greek respondents, on the other hand, are most inclined to use the warmest temperature (32 % wash their jeans at 60 °C).

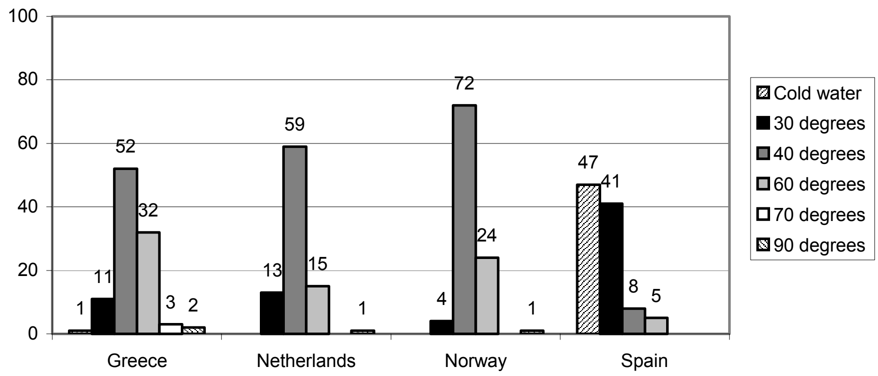

Figure 2-8. Temperatures jeans are washed at in different countries. Per cent.

2.4.4 T-shirts

Figure 2-9 shows that the respondents from the Netherlands are most likely to use a T-shirt only once before washing it, followed by Spain and then Norway. The Greek respondents are most likely to wear a T-shirt more times before washing it.

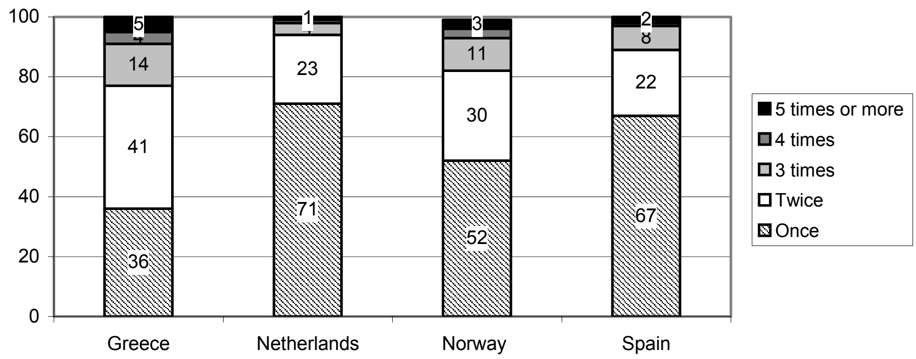

Figure 2-9. Frequency of changing T-shirts in different countries. Per cent.

Once more, even though almost all of the respondents wash their T-shirts in a washing machine, the temperature used differs considerably. Again the Spanish respondents tend to do their laundry in the coldest water. 48 % say they wash their T-shirts in cold water, and 30 % at 30 °C. The Norwegian respondents quote the highest temperatures (48 % wash their T-shirts at 60 °C). The overall pattern seems to be that the Norwegian and Greek respondents wear their T-shirts more than once before laundering them, but on the other hand they wash them in warmer water (Figure 2-10).

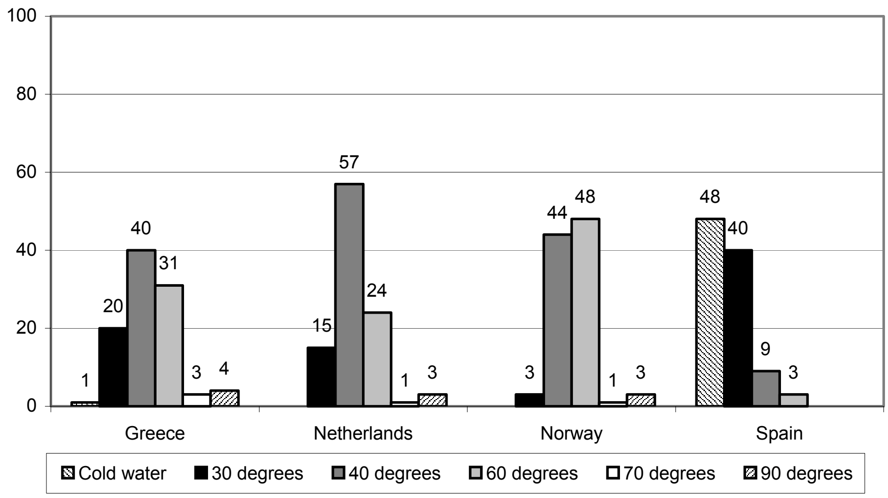

Figure 2-10. Survey of temperatures that T-shirts are washed at in different countries. Per cent.

2.4.5 Synthetic blouses or shirts

Synthetic blouses and shirts are considered more delicate than T-shirts. Figure 2-11 shows that 61 % of the respondents in the Netherlands and 60 % of the respondents in Spain change a synthetic blouse or shirt after they have used it once, compared to 33 % of the Greek respondents. The most common pattern in Greece is to change it after using it twice. In all the countries it is rare for a synthetic blouse or shirt to be used more than 3 times before it is washed.

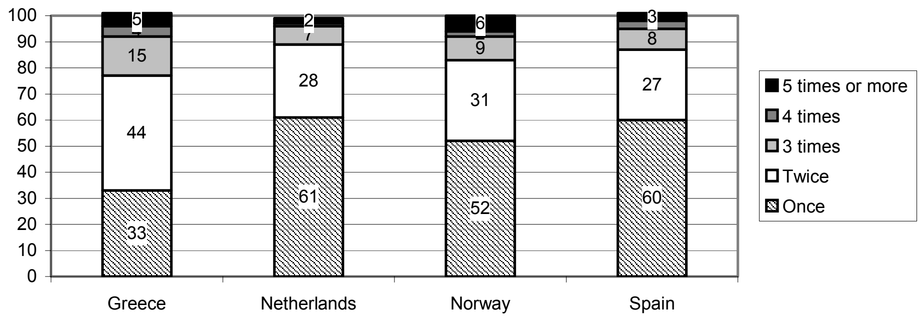

Figure 2-11. Frequency of changing a synthetic blouse or shirt in different countries. Per cent.

Synthetic fabrics are often delicate, and this is reflected in the way they are washed. Almost every household in the survey had its own washing machine, and most of the laundry is done in the washing machine. But many households seem to prefer to wash their synthetic blouses and shirts by hand. This is most common among the Greek respondents (17 %) and in Spain (14 %). The respondents from the Netherlands seem to be less inclined to wash their synthetic blouses and shirts by hand (7 %), and in Norway this is only slightly more common (9 % report laundering these items by hand).

Even though the way it is washed seems to indicate that synthetic fabric is more delicate, there are few respondents except in Spain who report that they launder these items in cold water. 55 % of the Spanish respondents wash their synthetic fabrics in cold water. The strongest tendency to use somewhat warmer water is in Greece and Norway, but the temperature used is seldom more than 40 °C. This pattern is the same as we have seen earlier.

2.4.6 Thin woollen sweaters

Almost all the respondents seem to have at least one thin woollen sweater. Thin woollen sweaters are delicate in the sense that wool gets damaged very easily and shrinks if it is washed too vigorously or in water that is too hot. Figure 2-12 reveals that the same pattern repeats itself. It is the respondents from Spain and the Netherlands that are most likely to wash their sweaters after a single use. A larger percentage of the Norwegian and Greek respondents quote that they use a thin woollen sweater several times before washing it. 29 % of the Norwegian respondents say they use it five times or more.

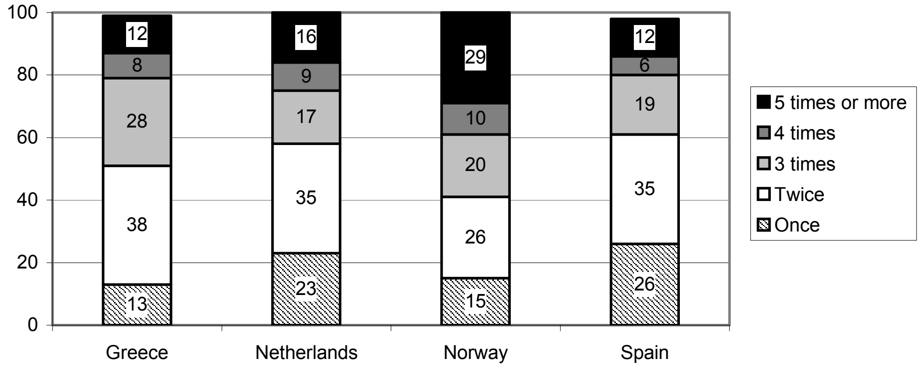

Figure 2-12. Frequency of changing thin woollen sweaters in different countries. Per cent.

Woollen sweaters are delicate, and many of them are washed by hand. This is most common among the Greek respondents, followed the Spanish and Norwegians. This means that it is among the respondents from the Netherlands we find the largest share who launder their thin woollen sweaters in a washing machine.

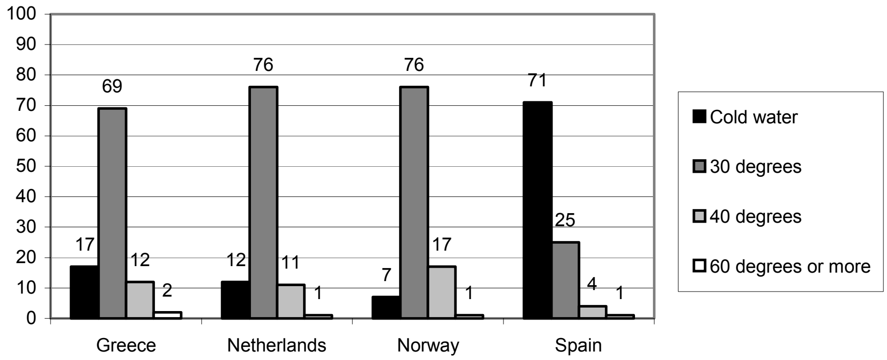

Figure 2-13. Survey of temperatures that thin woollen sweaters are washed at in different countries. Per cent.

Figure 2-13 shows that thin woollen sweaters are seldom washed at temperatures greater than 30 °C. Most of the respondents in Norway, the Netherlands and Greece seem to prefer to wash their sweaters at 30 °C, while the respondents in Spain once more reveal that they usually do their laundry in cold water. The figure also shows that the Norwegians are most likely to wash their woollen sweaters in somewhat warmer water.

2.4.7 Thin socks

The pattern is more or less the same for all four countries. It is most common to wear socks once before washing them. This is the pattern for 91 % of the Spanish respondents, closely followed by the respondents in the Netherlands (84 %). Again, the Norwegian respondents seem to change most seldom: 68 % after wearing them once, 20 % after wearing them twice, and 12 % after wearing them three times or more.

Thin socks are not always washed in a washing machine. This is most obvious among the Greek respondents, where 25 % wash their thin socks by hand, followed by the Spanish respondents (7 %). Washing thin socks by hand is more seldom among the Norwegian respondents, and among the respondents from the Netherlands this is very rare.

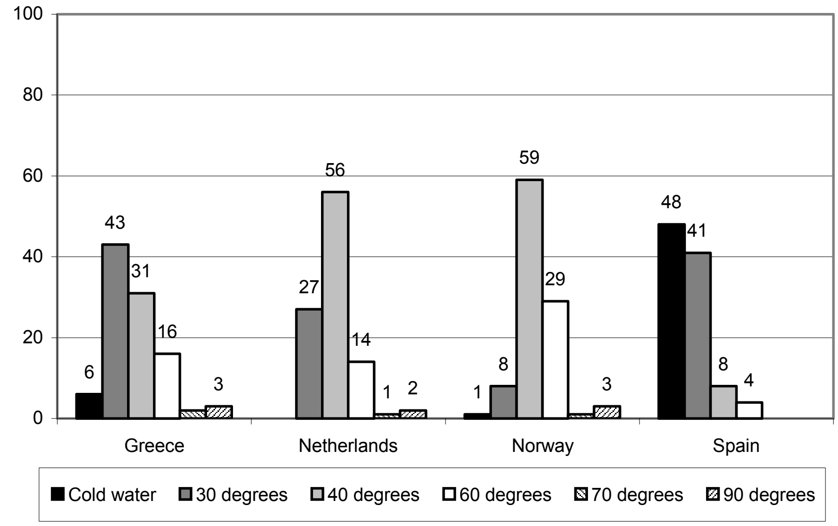

Figure 2-14. Survey of temperatures used for laundering thin socks in different countries. Per cent.

Again, when we examine washing temperatures the picture is more or less the same; the respondents in Spain wash their thin socks in cold water or not likely more than 30 °C. The respondents in the Netherlands seem to prefer

40 °C, while again the Norwegian respondents are most likely to wash their thin socks in the hottest water, closely followed by the Greek respondents.

2.4.8 Underpants

As underpants are worn next to the body, hygiene and smell are particularly relevant. This is manifested in the fact that the great majority in all of the countries change their underpants after one day of use. This tendency is strongest in Spain and the Netherlands, where 95 and 94 % report this. In Norway and Greece, respectively, 88 and 87 % change underpants after a single use. Those who do not change their underpants after using them once are most likely to change after using them twice.

In Norway and the Netherlands 98 % of the respondents wash their underpants in a washing machine. In Greece 12 % do the washing by hand, compared to 9 % in Spain. In Norway a greater percentage wash their underpants in a washing machine than those who own a private washing machine, but even those who do not own a private washing machine might have access to one.

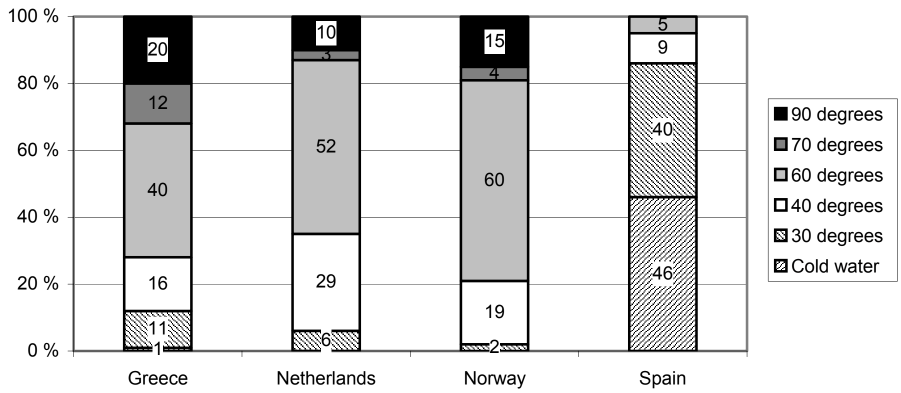

Figure 2-15. Survey of temperatures used for laundering underpants in different countries. Per cent.

Again it is the Spanish respondents who differ from the other countries in the survey by washing their garments in cold water or lukewarm water. This is quite in accordance with their answer to the statement that hot water wears out clothes much more than cold water (figure 2-15).

As a general rule underpants are washed at the warmest temperatures. For a majority of the respondents in the countries other than Spain it seems that 60 °C is the most common temperature for laundering underpants. The Greek respondents are most inclined to boil their underpants, followed by the Norwegians. On the whole, underpants are the garments that are changed most often and washed at the highest temperature.

2.5 Products used for doing laundry in the household

Our next question is what kind of products the respondents use when doing their laundry. In the questionnaire, nine different products were listed. Five of these are used directly when washing clothes (washing powder, washing tablets, washing liquids, detergents for wool and silk and detergents for coloured clothes), while four are not so directly connected to the washing process, but are still relevant. These are: stain remover, chlorine treatment or other bleaching agents, fabric conditioner, and a measuring cup for the dosage of detergents. In the following we shall have at look at the distribution of these products.

2.5.1 Detergents

It is among the Spanish respondents we find the greatest number of laundry products (on average 5.9) and among the respondents from the Netherlands we find the least. Our first task was to examine whether there are any differences between the countries when it comes to the use of detergents. Figure 2-16 presents these results graphically.

Table 2-3 Number of laundry products in the household in different countries. Mean. (N=3896)

Country	Mean
Netherlands	5.2
Greece	5.5
Norway	5.6
Spain	5.9

The respondents in all of the countries report that *washing powder* is the most common detergent (see figure 2-16). In Greece 96 % of the respondents use this product. Among the Spanish respondents it is somewhat less common – only 86 % use washing powder.

Washing tablets have been launched as a new way of doing laundry. These tablets ensure that you get the right dosage instead of using too much (or too little). However, tablets do not seem to be very popular in the countries surveyed. The largest percentage use tablets in Spain (32 % of the respondents) and the smallest percentage is among the Norwegians (only 23 %).

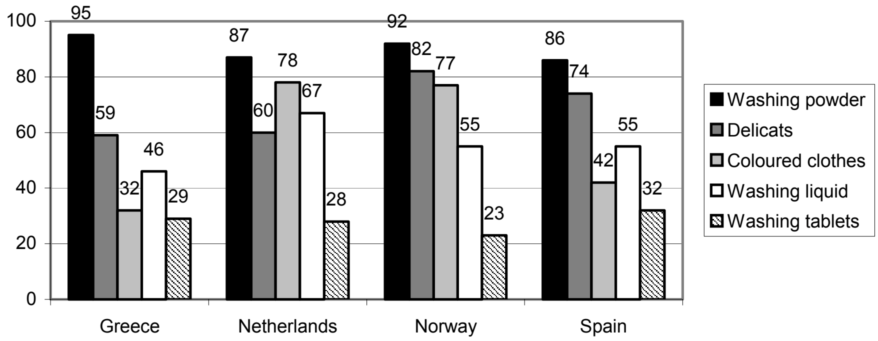

Figure 2-16. Share of respondents in different countries who use different detergents. Per cent.

Washing liquid seems to be quite popular among the respondents from the Netherlands, but not as popular among the others. 67 % of the respondents from the Netherlands report using washing liquid, whereas only 46 % of the Greek respondents use this product. The Norwegian and the Spanish respondents seem to be somewhere in the middle; 55 % of the respondents in these countries use washing liquid.

Different textiles need different treatment. Some are delicate and some need special treatment, for instance if you have *coloured clothes* and want to maintain the original colours. This seems to be the case for the respondents in the Netherlands and Norway, where 78 and 77 % respectively use detergents for coloured clothes. Only 32 % of the Greek respondents use this product. In Spain, detergents for coloured clothes are not easy to buy in the stores; just a few years ago the first detergents for coloured clothes were introduced on the Spanish market. Nowadays there are only 3 or 4 detergents without bleaching agents. Forty-two % of the Spanish respondents use detergents for coloured clothes.

If you have *delicate* garments made of wool and silk, you can use special detergents – known as gentle or fine wash detergents – for these fabrics. These detergents seem to be most popular among the Norwegian respondents (where 82 % report using fine wash detergents).

Summing up, we find that washing powder is the most ordinary detergent for laundering clothes. Almost every respondent reports using this. On the other hand, washing tablets are least commonly used. But the respondents in all of the countries use other detergents as well. Here we find some significant differences between the countries: the respondents in Norway and the Netherlands are more likely to use detergents for coloured clothes, while the respondents in Norway and Spain are more likely to use detergents for wool and silk, and as a general rule the Greek respondents are most likely to use washing powder.

2.5.2 Other laundry products

Fabric conditioners (also called fabric softeners) are the most commonly used of the other laundry products. 93 % of the Spanish and 91 % of the Greek respondents use fabric conditioners. The respondents in the Netherlands use fabric conditioners the least (only 66 %).

Using a *measuring cup for the dosage of detergent* is quite common, and most widespread between the Greek and the Spanish respondents. 86 % of the Greek respondents use a measuring cup compared to only 65 % of the Norwegians. Using a measuring cup might have some environmental advantages because it ensures appropriate dosage. In this perspective it is encouraging that more than two-thirds of the respondents use a measuring cup (assuming that without it there is a tendency to use more of the detergent than prescribed).

Stain remover is used for special purposes – i.e. if clothes are stained. About half of the respondents use stain remover. The respondents in the Netherlands are most likely to apply this, followed by the respondents from Spain. The Greek respondents are the least likely to apply stain remover (Figure 2-17).

One explanation could be that the Greek respondents are far more likely to *use chlorine or other bleaching agents* than the respondents from the Netherlands, where only 12 % use bleaching agents compared to 70 % of the Greeks. The Spanish respondents are even more likely to use bleaching agents (75 % answer this question in the affirmative). The Norwegian respondents seem to be in the middle, with 39 % reporting use of chlorine or other bleaching agents.

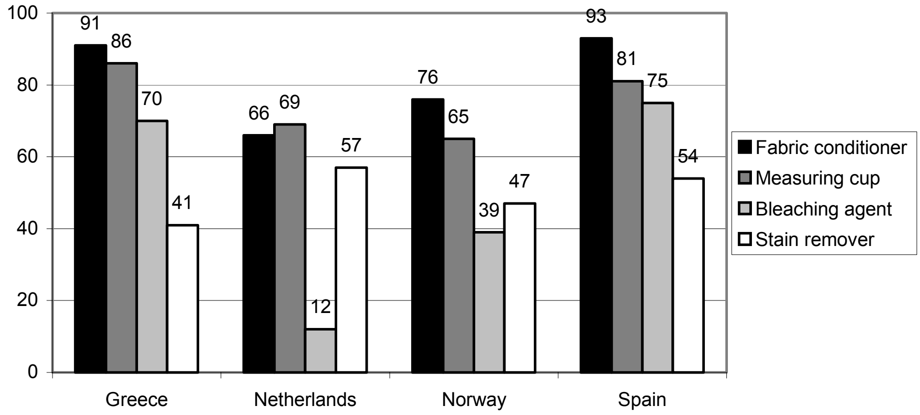

Figure 2-17. Survey of the use of different laundry products by respondents in different countries. Per cent.

The heavy use of chlorine and other bleaching agents among the Spanish respondents can be seen in relation to their use of cold or lukewarm water and the possibilities of getting clothes clean at these temperatures. The Greek respondents seem to be very eager to have white clothes. They are quite heavy users of bleaching agents, and at the same time they do their laundry at high temperatures.

2.6 Different generations – different laundry habits?

One of the conclusions in the analyses of the four countries was that laundry habits seem to be more or less in accordance with the respondents' attitudes on a national level. The next step is to examine whether attitudes and the way laundry is done differ from one generation to another in the four countries.

Using the ten different statements on attitudes towards laundry we conducted a factor analysis. Three factors emerged that illustrate three different orientations towards laundry.

Factor 1 indicates those who agree that people wash their clothes too often, that modern laundry habits are harmful to the environment, that washing wears out clothes more than wearing them does, and especially that hot water wears out clothes. In other words, this factor identifies those who feel that there is too much laundry being done.

Factor 2 signifies those who highly value cleanness. They strongly agree that clothes should smell as if newly laundered, that they should be hygienically clean and that it is embarrassing to wear clothes with a body odour.

Factor 3 signifies those who do not take doing laundry as seriously, but who want it to be practical. These respondents feel that today's detergents are so good that clothes get clean at low temperatures and that modern detergents keep clothes white anyway.

The next step was to investigate whether different generations have different orientations. An index ranging from 3 to 15 points was designed, where the lowest number of points signifies those who do not have this orientation, while the highest score signifies those with the strongest orientation[2]. Scores were then compared among the different age groups (table 2-4).

Table 2-4 shows that for all countries combined, orientations differ between the different age groups. The youngest respondents are less likely to share the opinion that too much laundry is done, and it is the middle generation who share this opinion most strongly (Factor 1). Factor 2 indicated those who highly value cleanness. This orientation is stronger among the older generations. Factor 3 signified those who do not seem to take laundry as seriously, but want it to be practical. This orientation is strongest among the oldest generation, revealing that members of this generation are not only the most concerned with cleanness, but they also have confidence in modern detergents and use these in a proper way.

In summary, attitudes towards laundry differ between generations. Members of the oldest generation seem to be more concerned with laundry; they value cleanness more highly and are not so inclined to take laundry lightly. The middle generation is a bit more inclined to feel that too much laundry is done. And probably this is the generation – the parental generation – which has to take care of the most laundry.

[2] For further details see SIFO project note [31]

Table 2-4 Scores of different age groups on the different factors in all the countries.

	Factor 1 Too much (N=3251)	Factor 2 Cleanness (N=3902)	Factor 3 Practical N=(3717)
Under 35 years	11.02	13.65	7.30
36-55 years	11.58	13.67	7.52
56 years and more	11.38	14.03	7.80

The next step was to investigate whether this pattern is the same in all countries. Table 2-5 illustrates some national differences. The Spanish respondents score highest on factor 1, that too much laundry is done. The Greek respondents have the highest scores on factor 2, i.e. valuing cleanness, and finally, the respondents in the Netherlands score highest on the orientation that laundry should be practical. So it appears that the Spanish respondents feel that too much laundry is being done and the Greek respondents seem to be most concerned about cleanness, while the respondents in the Netherlands seem to be more concerned about the practical aspects of the laundry process.

Table 2-5 Different age groups and their mean score on the different factors in four countries.

Country	Age groups	Factor 1	Factor 2	Factor 3
Greece	35 and under	10.9	14.7	7.1
	36-55 years	11.9	14.7	7.3
	56 years plus	12.0	14.6	7.7
Netherlands	35 and under	9.9	13.4	7.6
	36-55 years	10.4	13.2	7.8
	56 years plus	10.9	13.6	8.3
Norway	35 and under	11.0	12.8	6.6
	36-55 years	11.6	13.0	6.8
	56 years plus	10.9	13.8	7.2
Spain	35 and under	12.2	13.6	7.9
	36-55 years	12.4	13.9	7.9
	56 years plus	11.9	14.1	7.9

When it comes to different orientations between the generations, we find the orientation that *too much laundry is done* is strongest among the middle or older generation in all the countries. The elder Spanish generations do not have a strong orientation here, but the Spanish respondents have the strongest orientation overall.

We find the strongest orientation towards *cleanness* in the oldest generation. This goes for the respondents in the Netherlands, Norway and Spain. For the

Greek respondents we found no variation with age, but on the whole, it is the Greek respondents who share this orientation most strongly. The significance members of the older generation put on cleanness could be interpreted as representing values and traditions that have roots in a time when illnesses and risks of infection were a more relevant hazard.

Factor 3 designates an orientation towards laundry that it should be easy, i.e. not requiring high temperatures, and revealing quite a strong conviction that modern detergents can do the job. Quite surprisingly, it is the oldest generation who score highest on this orientation, except among the Spanish respondents who all have a strong opinion that laundry should be easy (Factor 3).

2.6.1 The oldest generation use their clothes the most times before washing them

The overall pattern in the analysis is that members of the oldest generation are the ones who use their clothes the greatest number of times before washing them. However, there are relatively small differences between the youngest and the middle-aged respondents. (For further information see Brusdal 2003)[32] This may suggest that in the future the young and middle-aged consumers of today will continue to wash clothes as often when they reach older age as they do now.

2.6.2 Different temperatures for different generations

Do washing temperatures differ according to generation? Table 2-5 shows the mean temperatures that different generations use for different textiles. Our point of departure is the questions in the survey regarding at what temperature the laundry was done. Cold water is given the value of 1 and 90 °C the value of 6 (i.e. the higher the score, the warmer the water).

With one exception, the table shows that it is the oldest generation who do their laundry in the warmest water. This is accordance with the same group's high score on factor 2, a factor stressing the importance of cleanness.

Our next question is whether this differs between the different countries. This is a complex question; a few highlights will be presented here. In the Netherlands members of the oldest generation tend to do their laundry at the highest temperatures. They are followed by the Norwegian sample, which also reflects a stronger tendency among the oldest to do their laundry at higher temperatures. However, when we turn to the Greek and Spanish respondents we find that it is members of the middle or younger generation who use the highest temperatures.

Table 2-6 Mean score of water temperature when washing different textiles for different age groups in all four countries.

	Under 35 years	36-55 years	56 years plus
Bed sheets	3.56	3.53	3.84
Bath towels	3.64	3.63	3.88
Jeans	2.81	2.75	2.90
T-shirt	2.92	2.84	3.10
Synthetic blouse/shirt	2.44	2.36	2.45
Thin woollen sweater	1.89	1.82	1.91
Thin socks	2.83	2.61	2.56
Underpants	3.44	3.37	3.61

2.6.3 Number of detergents differs with age

The number of detergents in a household will reveal something about how the laundry is done and how this affects the environment. The analysis shows that it is the middle generation which has the most detergents in the house, and the oldest generation which has the least. There may be many possible explanations for this. People in the age group between 36 and 55 tend to have the largest households, and having many persons in the household might require a greater variety of detergents. When comparing the younger and older generations it is interesting to note that the youngest generation has more detergents than the oldest generation. This could indicate that when these persons get older they will have as many detergents as the middle generation has today or even more. This is also contradictive to the findings that it was the middle generation who have a greater share of respondents who feel that people wash too much and often and that modern laundering is harmful to the environment.

Table 2-7 Average number of detergents according to age group in different countries.

	Under 35 years	36-55 years	56 years or more	Mean	N=
Greece	5.9	5.9	4.7	5.5	976
Netherlands	5.1	5.4	5.2	5.2	980
Norway	5.5	5.8	5.3	5.6	982
Spain	5.6	6.1	5.6	5.9	928

In studying differences between generations, it is often the youngest generation and what they do and think that is of greatest interest because they represent the future. When it comes to laundry it seems that the older or middle generations are the experts and the ones that are most concerned about cleanness and hygiene. Members of the middle generation have more laundry to do, and there is a tendency for them to feel that there is too much laundry being done. However, when comparing the youngest and oldest generation it is the youngest who have most products for doing laundry, a fact that does not look particularly promising for the environment.

When looking at the use of stain remover and fabric conditioners, we find that there are significant differences between the generations in almost every country and it is the youngest generations who use this most, sometimes followed by the middle generation. When it comes to bleaching agents we have seen earlier that the use differs considerably between the countries and it is less used in the Netherlands and Norway. When looking at the different generation in the different countries, the analysis shows that it is only among the Norwegian and Spanish respondents that we find significant differences. Bleaching agents are for both countries most used among the oldest generations.

3 Assessment of the functional performance of European laundry processes and detergents

Jan Tore Halvorsen Gunnarsen

3.1 Introduction

One of the most important functions of a laundering process is the wash performance, defined by the elimination of visible soil and stains from textiles. With the introduction of European ecolabelling systems for both detergents and washing machines, the focus on the ecological impact of doing laundry increased, and during the past 20 years the European countries have experienced a growing trend towards lower wash temperatures, as well as lower energy and water consumption (Kemna)[18]. Unfortunately, these parameters are all related to wash performance, and by lowering them we also reduce wash performance (Peel, Burnett, Ainsworth)[19]. Consumers may or may not accept a reduction in wash performance, and if the washing machines and detergents are not improved enough to equal this effect, we will sooner or later find that common European laundering practices move towards higher wash temperatures again. We have already experienced that consumers wash their clothes more often, which may be a way of solving the problem of a lower wash performance. Another way may be to use less environmental-friendly remedies more frequently. Unfortunately these are not good alternatives for the environment. Laundry habits are directly related to the satisfaction consumers find in having fresh, clean textiles; the prominence of these attitudes will differ from region to region.

Another important function in the laundry process is rinse performance. The low water consumption in domestic washing machines has increased the problems related to rinse performance. Low water consumption during the rinse process results in lower rinse performance (Sommer)[17]. There is a general feeling that detergent residues on textiles will lead to increased allergic problems and that zeolite dust could influence health. Many methods have been used to determine rinse performance (or rinse efficiency as it is also called), but unfortunately none have been proved reproducible. Thus there are no available data defining an acceptable level for rinse performance, but when tap water is used as a reference we might have a guideline. SIFO (the National Institute for Consumer Research) is represented in the working group appointed by the Nordic Council of Ministers to find a reproducible method for the determination of rinse efficiency, but this work has not yet been completed. For the time being the method described in the international standard IEC 60456:1998 “Clothes washing machines for household use – Methods for measuring the performance”[9] will be used.

For consumers’ health and well-being, it would be a great achievement if we knew what type of detergent yields the best rinse performance. That is of course the detergent type that is most easy to rinse out of the textiles. However, this may be a detergent with less than optimal wash performance.

Chemical substances in detergents and other used remedies are another factor of great importance, and legal demands to reduce problems for the environment have forced the detergent industry to use other more or less environmentally-friendly ingredients in an attempt to achieve the same wash performance. The detergents effect on the environment has not been a part of this research, but the results from will give a good background for further investigations into this.

In this research project we have investigated domestic laundry habits in four European countries (Greece, the Netherlands, Norway and Spain). The SAVE II study [18] showed that Greece still has a very high mean wash temperature (59 °C) compared to the mean wash temperature in Europe (47 °C). Spain is at the other end of the scale with a very low mean wash temperature (32 °C). Between these two countries and not much different from the mean European wash temperature, are the Netherlands (49 °C) and Norway (50 °C).

Two wash programmes (30 °C and 40 °C) were run using the most common detergents in each of the four European countries of interest. The only variation in this design is the type of detergent and the dosage. Thus the differences in wash performance of various European detergents can be determined. For each country involved, the most commonly used brand was selected for four types of detergents. We have labelled the detergent types A-D.

Table 3-1 Label of detergent types

Type A	Compacts (tablets) for white textiles
Type B	Traditional (powder) for white textiles
Type C	Liquid detergent for colored textiles
Type D	Compacts (tablets) for coloured textiles

The most interesting objective of this part of the research is to determine the wash performance of the most common laundry process for each country, using the most common detergent, the most common wash temperature and the most common water hardness in each of these countries. With these results, we will show the differences between a common Greek laundry process and a common Spanish laundry process. The differences in wash temperature are great, but are the differences in wash performance equally great? That is what we wish to measure: the wash performance of the most common laundry process in each country involved.

3.2 Testing conditions

The procedure used is based on the international standard IEC 60456:1998 "Clothes washing machines for household use – Methods for measuring the performance"[9] with modifications from the work document IEC 59D/207/CD [20], which is an improvement on the current standard. This test method is used internationally for the determination of the wash performance of washing machines, and in Europe for the determination of wash performance of detergents for ecolabelling purposes.

The wash performance and rinse efficiency of each detergent is determined after five wash cycles with a fixed water hardness of 14°dH. Each detergent is tested using a 30 °C and a 40 °C wash programme. Tests are run in parallel in five identical household washing machines (AEG Eco-Lavamat 6350 – front loader).

Additionally, the two most common laundry processes in each of the four European countries are tested for wash performance. In this particular test three cycles are run. The fact that only three cycles are used for these tests will mean a higher confidence interval, and some of the differences that we find not significant might have been significant if five cycles were run. The reason for only three cycles was several delays in the project plan, and eventually there was not enough time to do tests as planned. The laboratory used was moving to a new location, which made it impossible to continue the tests for more than three cycles.

The dosage of each detergent was selected from what was labelled on the detergent package. Water hardness was determined according to the international standard IEC 60734, Type B[21]. The most common Norwegian water hardness (3 °dH) differed considerably from the one tested under fixed conditions, and the Norwegian detergents were labelled with a lower dosage for this low water hardness. That is why the two tests of the Norwegian detergents are performed with two different levels of water hardness, as the only detergents in this test.

Different types of soiled test fabrics are washed together with a cotton base load in a washing machine.

Table 3-2 Soiled test fabrics

Type of soil[3]		Use (detects)[4]
IEC Carbon black/Mineral oil on CO	EMPA 106	Detergency
IEC Blood on CO	EMPA 111	Bleach, Protease enzyme activity
IEC Cocoa on CO	EMPA 112	Detergency, Protease and Amylase enzyme activity
IEC Red wine on CO	EMPA 114	Bleach
Protein/Tea on CO	wFk 10 JE	Bleach, Protease enzyme activity
Lipstick on CO	wFk 10 LS	Detergency, Lipase enzyme activity
Starch/Pigment on CO	wFk 10 R	Detergency, Amylase enzyme activity
Protein/Tea on PES/CO	wFk 20 JE	Bleach, Protease enzyme activity
Lipstick on PES/CO	wFk 20 LS	Detergency, Lipase enzyme activity
Starch/Pigment on PES/CO	wFk 20 R	Detergency, Amylase enzyme activity
Protein/Tea on PES	wFk 30 JE	Bleach, Protease enzyme activity
Lipstick on PES	wFk 30 LS	Detergency, Lipase enzyme activity
Starch/Pigment on PES	wFk 30 R	Detergency, Amylase enzyme activity

The IEC soiled test fabrics for the evaluation of wash performance were originally developed for high temperatures and even boil wash programs. However, they are still in use for low temperatures and for tests of wash performance for ecolabelling detergents using a 40 °C wash programme. The soiled test fabrics in the lower six rows in the table were not used for evaluations in this particular study. These are soils on polyester and polyester/cotton

[3] Fabric substrates: CO = cotton, CO/PES = polyester/cotton 65/35, PES = polyester.
[4] This column gives the use of the soiled test fabrics, suggested by wFk. More information has to be collected from wFk and EMPA.

fabrics. In the present research project the evaluation is focused on the soiled cotton test fabrics.

Determination of wash performance

The composition and age of the base load is according to IEC 59D/207/CD [20]. Base load items are hung singly and separately in a conditioned room with temperature fixed at (20 ± 2) °C and an ambient humidity fixed at (65 ± 5) %, for at least 15 hours. This is done between each exchange of base load items. After conditioning the items are weighed and this weight is used to calculate the remaining moisture in the base load after a wash cycle. The test load in each wash cycle consists of base load and soiled test fabrics. The soiled test fabrics are defined in table 3.2. Two soiled test fabrics of each type are added in each wash cycle, making a total of 14 soiled test fabrics in each wash cycle. All soiled test fabrics are added to the base load in the same order, with plastic fasteners attached. Direct contact between different soiled test fabrics is avoided as far as possible. The weight of the conditioned test load is (3500 ± 60) g for all wash cycles.

Table 3-3 Loading of 3,5 kg test load

Step	Type of item	Number
1	Towels	3
2	Towel + IEC soiled test fabrics (EMPA 105)	1
3	Bedsheet	1
4	Towel + soiled test fabrics (wFk – 10JE, 10LS, 10R, 20JE, 20LS, 20R)	1
5	Pillowcases	2
6	Towel + soiled test fabrics (wFk – 10JE, 10LS, 10R, 30JE, 30LS, 30R)	1
7	Bedsheet	1
8	Towel + IEC soiled test fabrics (EMPA 105)	1
9	Pillowcase	1
10	Towel + soiled test fabrics (wFk – 20JE, 20LS, 20R, 30JE, 30LS, 30R)	1
11	Towels	2 - 3

The manner of folding the items before loading the washing machine is described in IEC 59D/207/CD [20].

Between each wash cycle a start-up programme is run to make sure that conditions are the same for all tests. For each wash cycle, new soiled test fabrics are used.

After completion of a wash cycle, the soiled test fabrics are dried by ironing and left in the dark until reflectance measurements are taken.

Reflectance measurements of the washed soiled test fabrics are made with a spectral photometer. This measurement of the tristimulus value Y is used as a measure of the wash performance. The main spectral photometer used in these measurements is a Minolta CM-3610d with SpektraMagic software. Some of the measurements are made with a Minolta CM-508d to gain time. To eliminate any differences this might have caused, we used the same spectral photometer to measure the same soiled test fabrics. All results are shown as an average of the reflectance values of all soil types used, except for the detergents for coloured textiles. When evaluating these we have excluded the soils for detecting bleaching effects. We have used a 95 % level of confidence to determine whether the differences are significant.

Determination of the rinse efficiency

As a method to find rinse efficiency we have used the test described in IEC 60456:1998 [9]. This is a test using the residual alkalinity of the detergent solution in a base load after spin extraction as a measure of rinse efficiency. The increased alkalinity concentration in the spin extracted water from the base load is used, related to the alkalinity concentration in the water supply.

To find this we need samples from the water supply during tests. Three samples are taken from the water supply at different stages of the wash cycle. These samples are measured for pH, water hardness (°dH) and water inlet temperature. To find the alkalinity, 100 grams of the water supply sample is titrated with 0.02 N HCl to 4.0 pH at a specific time using a microburette.

After a complete wash cycle, the test load is removed immediately and the weight of the base load is measured to calculate the remaining moisture. The base load is transferred to an external spin extractor and the residual water is extracted to find the residual alkalinity in the base load. The base load was spun with the external spin extractor for 5 minutes. This yielded a detergent solution that we mixed thoroughly and divided into three test samples for measuring alkalinity.

The extracted test samples were measured to find the alkalinity, using the same method as for the water supply samples. During the rinse efficiency tests with the 30 °C wash programme, we found that some detergents gave a lower residual moisture level than we had expected. Because of this we reduced the volume of the test samples for tests with the 40 °C wash programme. For test samples from these tests, only 50 grams of detergent solution were used.

This method of measuring rinse efficiency is under consideration by working groups within the standardization committees IEC SC 59D and CENELEC TC 59X.

Calculation of the alkalinity is described in IEC 60456:1998 [9]. We have used a 95 % level of confidence to find if the differences are significant.

3.3 Wash performance detergents

3.3.1 Test design

The following tables show the detergents selected for each country and the dosage administered. The water hardness used is 14 °dH.

Table 3-4 Textile detergents selected from Greece

Detergent	Skip	Skip	Ariel Essential Alpine	Skip[5]
Code detergent	G-A	G-B	G-C	G-D
Type of detergent	Tablets	Traditional	Liquid	Tablets
Detergent for coloured textiles (yes/no)	no	no	Yes	no
Dosage	2 tablets = 82.1 g	130 mL = 79.0 g	75 mL = 78.0 g	2 tablets = 78.5 g

Table 3-5 Textile detergents selected from The Netherlands

Detergent	Ariel	Omo	Robijn Intensief	Ariel Color
Code detergent	NL-A	NL-B	NL-C	NL-D
Type of detergent	Tablets	Conc. powder	Liquid	Tablets
Detergent for coloured textiles (yes/no)	no	no	Yes	yes
Dosage	2 tablets = 86.1 g	84 mL = 79.0 g	60 mL = 61.0 g	2 tablets = 84.5 g

As table 3-5 shows, the Netherlands has selected a compact detergent as the code B detergent, which should have been a traditional detergent. This is because we could not find a commonly used traditional detergent in the Netherlands.

[5] This detergent should have been a Greek detergent for coloured textiles, but we found that the Greek detergent for white textiles have been tested instead.

Table 3-6 Textile detergents selected from Norway

Detergent	Omo Ultra	Omo Taed Plus	Omo Color	Omo Color
Code detergent	N-A	N-B	N-C	N-D
Type of detergent	Tablets	Traditional	Liquid	Tablets
Detergent for coloured textiles (yes/no)	no	no	Yes	yes
Dosage	2 tablets = 86.2 g	165 mL = 103.3 g	60 mL = 60.0 g	2 tablets = 85.9 g

Table 3-7 Textile detergents selected from Spain

Detergent	Puntomatic	Ariel Alpine	Micolor Gel	Puntomatic Color
Code detergent	E-A	E-B	E-C	E-D
Type of detergent	Tablets	Traditional	Liquid	Tablets
Detergent for coloured textiles (yes/no)	no	no	Yes	yes
Dosage	2 tablets = 68.9 g	190 mL = 127.0 g	135 mL = 143.0 g	2 tablets = 60.8 g

A reference detergent is tested in parallel with the other detergents, both with and without sodium perborate tetrahydrate (SPB) and bleach activator TAED. This is reference detergent A* in IEC 59D/207/CD [20].

3.3.2 Results

This section presents the assessment of the detergents' wash performance in the four European countries. The test was conducted under fixed conditions, and the results evaluated should be comparable with regard to the differences between the detergents tested.

Wash performance of detergents for white textiles

Detergent types A and B are compacts and traditional detergents (respectively) which are specifically designed to keep textiles white. Thus we call them detergents for white textiles. Results are shown in table 3-8.

Greece and Spain seem to have the detergents for white textiles with highest wash performance. Both countries are known to use traditional detergents most commonly, and it is interesting to see that the Spanish traditional detergent tested has a better wash performance than the compact detergent tested. This is probably the reason why Spanish consumers choose traditional detergents instead of compacts, presuming that this is true in general for these two types. The traditional detergent (Ariel Alpine) tested is also the only detergent from Spain which was probably developed outside of Spain (by Proctor & Gamble, Switzerland). Greece has a good wash performance for the compact detergent, but the traditional detergent has significant lower wash performance than the Spanish traditional detergent. At 30 °C they are in fact significantly different. Greek consumers tend to use a much higher wash temperature than the Spanish, and this detergent might not be designed for low temperatures when produced for the Greek market. And as we see in the results, the performance of the Greek traditional detergent is highly dependent on temperature.

Table 3-8 Average wash performance of compacts and traditional detergents

	30 °C		**40 °C**	
	Compact (A)	*Traditional (B)*	*Compact (A)*	*Traditional (B)*
*Ref A**	*-*	*59.81 (± 1.21) %*	*-*	*62.39 (± 0.62) %*
Greece	**61.06 (± 1.58) %**	58.46 (± 1.43[6]) %	**63.59 (± 1.03) %**	63.02 (± 0.68) %
NL	59.35 (± 1.02[7]) %	59.62 (± 1.75[8]) %	62.11 (± 0.52) %	62.57 (± 0.71) %
Norway	57.86 (± 1.04) %	59.32 (± 2.00[9]) %	61.49 (± 1.00) %	61.08 (± 0.28) %
Spain	57.28 (± 2.48[10]) %	**61.22 (± 0.87) %**	61.05 (± 1.85) %	**63.24 (± 0.87) %**

The Norwegian detergents have relatively low wash performance at both temperatures. The results for both Norwegian detergents at 40 °C are in fact comparable to the wash performance for the Spanish traditional detergent at 30 °C. The Greek compact detergent has a significantly higher wash performance than the Norwegian at both temperatures.

When we examine the results for the Netherlands, we find that the compact detergent and the traditional detergent are very similar in wash performance. The results are also dependent on temperatures.

Specific soiled test fabrics to consider

With regard to specific soiled test fabrics, we detect a significant high effect on the carbon black/mineral oil soil (EMPA 106) for the Greek compact detergent compared to the other compact detergents. For the Spanish compact detergent we detect a significant low effect on the protein/tea soil (wFk 10

[6] Only four cycles are evaluated.
[7] Only four cycles are evaluated.
[8] Only four cycles are evaluated.
[9] Only three cycles are evaluated.
[10] Only four cycles are evaluated.

JE), for detection of bleaching performance (and some protease enzyme activity).

We may detect a lower effect on the lipstick soil (wFk 20 LS) for the Greek traditional detergent at 30 °C.

Wash performance of detergents for coloured textiles

Detergent types C and D are liquid detergents and compacts, and are meant to be used for coloured textiles. They should not contain bleaching agents. Results are shown in table 3-9.

Table 3-9 Average wash performance of detergents for coloured textiles

	30 °C		40 °C	
	Liquid (C)	*Compact (D)*	*Liquid (C)*	*Compact (D)*
*Ref A**	*-*	*55.73 (± 0.65) %*	*-*	*56.43 (± 0.59) %*
Greece	48.02 (± 0.71) %	-	49.49 (± 1.03) %	-
NL	46.80 (± 0.65) %	**56.29 (± 0.76) %**	47.13 (± 0.74) %	56.33 (± 1.33) %
Norway	**49.92 (± 1.18) %**	55.88 (± 1.08) %	**50.37 (± 0.91) %**	56.10 (± 0.71) %
Spain	41.95 (± 0.78) %	55.45 (± 1.04) %	41.62 (± 1.41[11]) %	**56.44 (± 1.98) %**

All the liquid detergents we tested have a significantly lower wash performance than the compact detergents tested. The difference is very great. In fact, the wash performance when using water is similar to using the Spanish detergent. The dosage used for the Spanish detergent is quite high, and this may have caused the very bad results for this particular detergent. The low results, combined with the extremely high foam level during testing, may indicate that a different programme with less mechanical action and less programme duration is more likely to be used for this detergent in Spain. With regard to specific soiled test fabrics, we detect an extremely low effect on blood soil (EMPA 111) and cocoa soil (EMPA 112) for the Spanish detergent.

The liquid detergents from the other countries are significantly better than using just water, but in terms of wash performance alone we would advise consumers to use other types of detergents. These liquid detergents are simply not good enough.

With 67 % of the Dutch consumers having liquid detergents in their home, they are the “big” users of this type of detergent. 79 % say they have colour

[11] Only four cycles are evaluated.

detergents as well. With this in mind it is disappointing that the wash performance is relatively low for the tested Dutch detergent.

The compact detergents for coloured textiles are significantly better than the liquid detergents, and the results are similar to those for the detergents for white textiles when bleaching is not considered. The detergents tested are quite similar regarding wash performance, and none of them are dependent on temperature.

3.4 Comparison of European laundry processes

3.4.1 Test design

The four countries participating in this investigation were asked to provide information about their two most common laundry processes. We wanted to test the most common wash temperatures and water hardness with the most commonly used detergent in each country. Unfortunately our household washing machines have no option for temperatures lower than 30 °C and because of this the wash temperature for Spain was set to 30 °C for coloured textiles. The most common wash temperature for coloured textiles in Spain is in fact 15 °C. The laundry processes used are listed in table 3-10 and table 3-11.

Table 3-10 Most common wash processes for white textiles in four European countries

	Greece	The Netherlands	Norway	Spain
Detergent	Skip	Ariel	Omo Ultra	Ariel Alpine
Code detergent	G-B	NL-A	N-A	E-B
Type of detergent	Traditional	Tablets	Tablets	Traditional
Water hardness	15.4 °dH	9.0 °dH	3.0 °dH	9.0 °dH
Wash temperature	60 °C	60 °C	60 °C	40 °C
Dosage	130 mL = 79.0 g	2 tablets = 86.1 g	1 tablet = 43.1 g	190 mL = 127.0 g

Table 3-11 Most common wash processes for coloured textiles in four European countries

	Greece	The Netherlands	Norway	Spain
Detergent	Skip[12]	Ariel Color	Omo Color	Micolor Gel
Code detergent	G-D	NL-D	N-D	E-C
Type of detergent	Tablets	Tablets	Tablets	Liquid
Water hardness	15.4 °dH	9.0 °dH	3.0 °dH	9.0 °dH
Wash temperature	40 °C	40 °C	40 °C	30 °C
Dosage	2 tablets = 78.5 g	2 tablets = 84.5 g	1 tablets = 43.0 g	135 mL = 143.0 g

From the results we may compare the most common wash performances in each country.

We conducted tests using the reference detergent under the same conditions. These are listed in table 3-12 and table 3-13.

Table 3-12 Reference detergent A* (with SPB and TAED) used for comparison of wash processes for white textiles

	Greece	The Netherlands	Norway	Spain
Water hardness	15.4 °dH	9.0 °dH	3.0 °dH	9.0 °dH
Wash temperature	60 °C	60 °C	60 °C	40 °C
Dosage base powder	84.7 g	84.7 g	84.7 g	84.7 g
Dosage SPB	22.0 g	22.0 g	22.0 g	22.0 g
Dosage TAED	3.3 g	3.3 g	3.3 g	3.3 g

Table 3-13 Reference detergent A* used for comparison of wash processes for coloured textiles

	Greece	The Netherlands	Norway	Spain
Water hardness	15.4 °dH	9.0 °dH	3.0 °dH	9.0 °dH
Wash temperature	40 °C	40 °C	40 °C	30 °C
Dosage base powder	84.7 g	84.7 g	84.7 g	84.7 g

3.4.2 Results of European laundry processes for white textiles

This section presents the assessment of wash performance using the most common laundry processes in four European countries, with regard to the detergent types A and B. These are compacts and traditional detergents specialized to keep the textiles white. Thus we call them detergents for white textiles.

[12] This detergent should have been a Greek detergent for coloured textiles, but we found that the Greek detergent for white textiles have been tested instead.

Figure 3-1 shows that the most common laundry processes in the Netherlands and Greece tend to give a higher wash performance than the processes in Norway and Spain. We find a significant difference between the wash performances using the most common Dutch and Greek laundry processes and the wash performance using the most common Spanish laundry process. The detergents from the Netherlands and Greece have been tested at a temperature of 60 °C, while the Spanish detergent has been tested at 40 °C. This indicates that the Spanish detergent is not able to give as high a wash performance as the other two when used at a lower wash temperature.

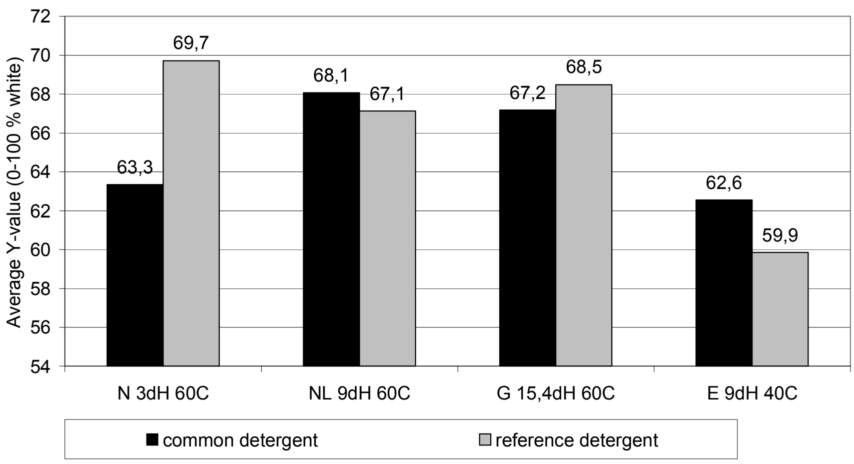

Figure 3-1 Wash performance of the most common laundry processes for white textiles

An interesting discovery from this comparison is the fact that the most common detergents in Spain and Norway (respectively) seem to have about the same average value on wash performance even though the Norwegian detergent is tested using a higher wash temperature and lower water hardness. The Norwegian detergents seem to have a lower wash performance than we would expect when tested at the most common Norwegian condition. This indicates that the Norwegian detergent is not properly adapted to the common Norwegian laundry processes. Another possibility is that the dosage declared on the package is too low. If we compare the wash performance for the reference detergent A* for the most common Norwegian and Spanish condition, we find a very high difference. We may conclude that Norwegians consume a lot more energy during washing than the Spanish to gain the same wash performance for their white textiles.

A significant difference is found between the Norwegian compact detergent, N-A, and the reference detergent A*, when tested under the most common Norwegian wash conditions. This discovery strengthens the assumptions above. If we compare the detergents from Greece, the Netherlands and Spain with the reference detergent A* when tested using their respective common wash conditions, we discover that this is not the case for these detergents. In fact, the most common laundry process in Spain tends to have a higher wash performance than for the reference detergent under the same conditions.

3.4.3 Results of European laundry processes for coloured textiles

This section, presents the assessment of wash performance using the most common laundry processes in four European countries, with regard to detergent types C and D. These are liquid detergents and compacts (respectively) and are meant to be used for coloured textiles.

A significant difference is found between the Spanish liquid detergent, E-C, and the reference detergent A*, when tested using the most common Spanish wash condition. The wash performance for the Spanish liquid detergent is remarkably low, as we have seen when evaluating the tests under fixed conditions. This detergent (under our test conditions) is not recommended for any laundry process due to the fact that the wash performance is too low. But the results may be influenced by the very high foaming level of the Spanish detergent.

Figure 3-2 shows that the most common laundry processes for coloured textiles in the Netherlands and Norway are very similar in wash performance. The Spanish laundry process using liquid detergent, however, yields significantly lower performance than all the others, as we explained earlier.

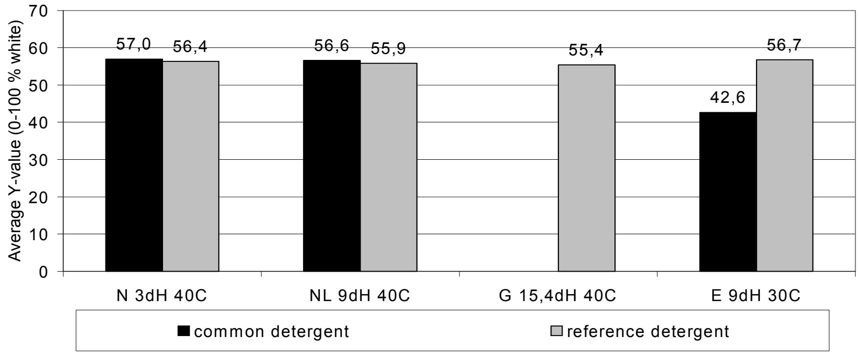

Figure 3-2 Wash performance of the most common laundry processes for coloured textiles

3.5 Effects of wash temperature and water hardness on wash performance

How dependent is the wash performance on temperature?

Common knowledge suggests that a higher wash temperature will give a higher wash performance. For water hardness the opposite applies: higher water hardness means a lower wash performance. With this in mind, we may have a look at figure 3-3. In this figure we show the results of wash performance using the most common laundry processes in the countries investigated and comparing them to the results of wash performance under fixed conditions.

As all detergents have been tested for wash performance at both 30 °C and 40 °C with the same level of water hardness, we may compare these results and find how dependent these detergents are on wash temperature. We will also try to evaluate figure 3-3, with regard to the differences between the tests under fixed conditions and the tests using common laundry processes.

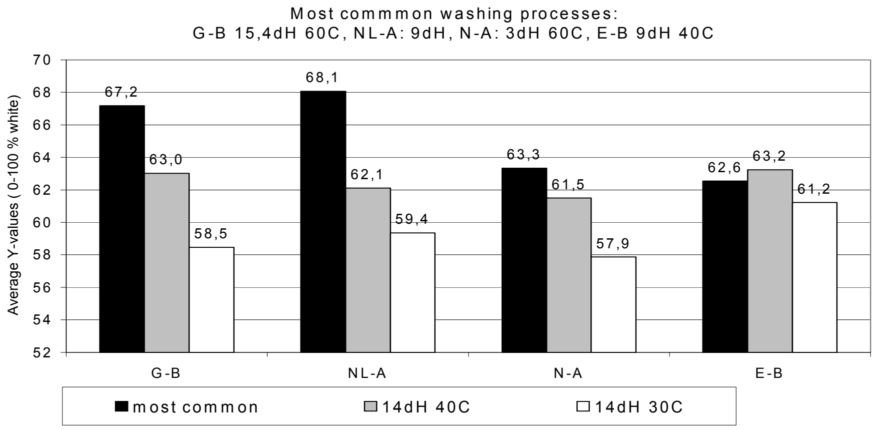

Figure 3-3 Effects of wash temperature and water hardness

Spain

We know from the consumer laundry habits survey presented in this research and the SAVE II study that it is most common in Spain to wash at low temperatures, and that the most common detergent type used in Spain is a traditional detergent. When comparing the wash performance at 30 °C and 40 °C, we find that only the traditional detergent, E-B, is significantly dependent on temperature. We have to remember that this detergent is not produced in Spain, as the only one of the types of detergent selected from the Spanish market. This may be the reason why this detergent is dependent on temperature. It may indicate that the other detergents tested are more adapted to the Spanish market when it comes to temperature.

Figure 3-3 shows that lowering the water hardness from 14°dH to 9 °dH does not affect the wash performance of detergent E-B.

Greece and the Netherlands

Greece has a high mean wash temperature of about 60 °C (SAVE II study)[8], and we would expect Greek detergents to be dependent on temperature. This effect is significant for the traditional detergent, which is the most commonly used detergent type in Greece.

The Netherlands have temperature-dependent detergents of type A and B, which are the compact detergent and the traditional detergent, both with bleaching agents. These types of detergents are the most common to use at higher temperatures, so it makes sense that they are temperature dependent.

As already stated, the Dutch compact detergent, NL-A, and the Greek traditional detergent, G-B, are dependent on temperature, when comparing tests at 30 °C and 40 °C. As we may see from figure 3-3, this is also the case when we look at the results for 60 °C. The wash performance at 60 °C is significantly higher than the wash performance at 40 °C for both NL-A and G-B. However, the water hardness for these two is different for the 60 °C programme. G-B was tested at 15.4 °dH at 60 °C and 14 °dH at 30 °C and 40 °C. NL-A was tested at 9 °dH at 60 °C and 14 °dH at 30 °C and 40 °C.

When comparing the results for the Greek detergent, we see that there is a higher difference in the wash performance at 30 °C compared to 40 °C than at 40 °C compared to 60 °C. This may indicate that the latter difference is due to the higher water hardness used in the tests at 60 °C. But caution must be used in drawing conclusions; the reason for this difference might be that this detergent contains ingredients that become more active between 30 °C and 40 °C, which is why the effect is not as great when we increase the temperature.

For the Dutch detergent we see a very high increase in wash performance between 40 °C and 60 °C. The difference is higher than between 30 °C and 40 °C. This difference is also higher than the difference between the wash performance at 40 °C and 60 °C for the Greek detergent. As the water hardness is lower for the test at 60 °C for the Dutch detergent, this may indicate that a synergic effect of these two parameters yields the high increase in wash performance. But it may also be that this detergent contains ingredients that become more active between 40 °C and 60 °C.

If we investigate the type D detergent from Greece and the Netherlands, we find no differences between tests using common laundry processes and tests using fixed conditions. These detergents are tested using the same wash temperature (40 °C), but with different hardness. This shows that different water hardness yields no differences in results when operating with the same temperature.

Norway

This study has shown that people in Norway use a relatively high wash temperature, but this does not seem to have an effect on temperature dependency of the tested detergents. Only the compact detergent with bleaching agents is significantly dependent on temperature, when we compare tests at 30 °C and 40 °C.

Figure 3-3 may indicate that the most common Norwegian detergent, N-A, does not yield a significantly higher wash performance when used at 60 °C instead of 40 °C. That would have been a very interesting result, especially when we know that the water hardness is very low for the test at 60 °C. But unfortunately for this evaluation, the dosage of N-A in this test is only half of the dosage in the fixed test. The detergent is labelled with different dosages for different water hardness, and with different dosages it is very difficult to analyse the effect temperature and water hardness have on the wash performance of this detergent. It is also difficult to compare the wash performance of N-A under the most common Norwegian conditions with the wash performances of the detergents form the other countries, as the dosages are very different. But as figure 3-3 shows, N-A with the lowered dosage has a wash performance at about the same level as for the 40°C programme in the other countries.

3.6 Rinse efficiency of European detergents

Two wash programmes were run (at 30 °C and 40 °C) using the most common detergents in the four European countries of interest. The only variation in this design is the type of detergent and the dosage of the detergent. This test was run in parallel with the test of wash performance in section 3.3, and the same test design was used with regard to the detergents and dosages selected.

This is a test using the residual alkalinity of the detergent solution in a base load after spin extraction as a measure of rinse efficiency. The increased alkalinity concentration in the spin extracted water from the base load is used, related to the alkalinity concentration in the water supply. In this section we will show the rinse efficiency of each detergent tested. It should be noted that the method used is under consideration, and that the values of rinse efficiency shown are not reproducible and cannot be compared from laboratory to laboratory (as the values of rinse efficiency are completely dependent on the laboratory performing the test).

When testing rinse efficiency, we had some difficulties with the Spanish detergents. The main problem was a high level of foaming during testing; as a result the rinse efficiency of these detergents should be interpreted with some caution. Results are shown as an average of the alkalinity measured. Low alkalinity is a measure of high rinse efficiency.

We find that the liquid detergents have high rinse efficiency compared to the other types of detergents. This is valuable information for people with allergic reactions from residual detergent after wash.

Greece (and Spain for compact and liquid detergent) has high rinse efficiency for all detergents tested. The Netherlands has quite low rinse efficiency compared to the Greek detergents, except for the liquid detergent.

Temperature does not seem to be an important parameter for rinse efficiency.

Table 3-14 Average rinse efficiency – high and low

	Temp.	Highest		Lowest	
Compacts (A)	30 °C	Greece	0.10 (± 0.05)	The Netherlands	0.52 (± 0.18)
	40 °C	Greece	0.09 (± 0.04)	The Netherlands	0.50 (± 0.12)
Traditional (B)	30 °C	Greece	0.18 (± 0.08)	Spain	0.54 (± 0.15)
	40 °C	Greece	0.22 (± 0.03)	Spain	1.72 (± 0.60)
Liquid	30 °C	Spain[13]	-0.05[14] (± 0.32)	The Netherlands	0.05 (± 0.03)
– Colour (C)	40 °C	Norway	0.07 (± 0.07)	The Netherlands	0.15 (± 0.04)
				Spain[15]	0.15 (± 0.83)
Compacts	30 °C	Spain	0.17 (± 0.07)	The Netherlands	0.42 (± 0.17)
– Colour (D)	40 °C	Spain	0.27 (± 0.13)	The Netherlands	0.55 (± 0.14)

In this evaluation we have focused on the compacts and traditional detergents for white textiles and the liquid detergent for coloured textiles. The results for the compacts for coloured textiles are not much different than the results for the compacts for white textiles.

Compacts (type A)

The detergent from Greece gives the lowest level of alkalinity left in the base load after both wash programmes. A significant difference is found between

[13] Tests at 40 °C with the Spanish liquid detergent (type C) were interrupted for the same reason as for the 30 °C wash programme. Only two cycles could be measured.

[14] A negative value is reported when the measured alkalinity of the water supply becomes higher than the measured alkalinity of the detergent solution. We believe that the detergent is completely rinsed out of the base load in such cases.

[15] Tests at 40 °C with the Spanish liquid detergent (type C) were interrupted for the same reason as for the 30 °C wash programme. Only two cycles could be measured.

the rinse efficiency for the Greek detergent, G-A, and the Dutch detergent, NL-A, at both wash temperatures.

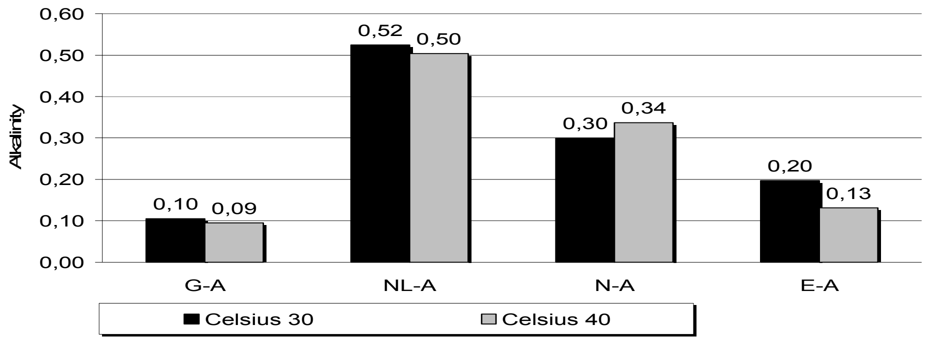

Figure 3-4 Average rinse efficiency of type A – Compacts for white textiles

Traditional detergents (type B)

The detergent from Greece gives the lowest level of alkalinity left in the base load after both wash programmes. This detergent has significantly higher rinse efficiency than the other detergents at both wash temperatures.

As figure 3-5 shows, the Spanish detergent, E-B, gives a very high level of alkalinity at 40 °C. We cannot explain this unexpected difference in alkalinity between the two wash programmes for this.

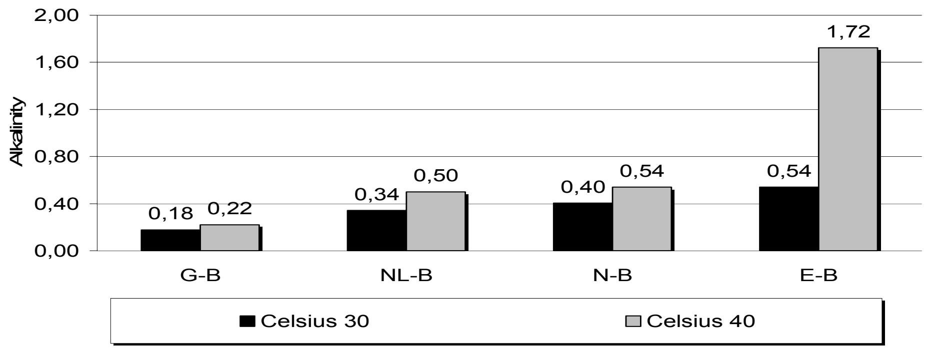

Figure 3-5 Average rinse efficiency of type B – traditional detergents for white textiles

If we compare these values with values from the compacts for white textiles, we find that traditional detergents tend to give lower rinse efficiency than the compacts. This is the case for all countries except for the Netherlands, where no traditional detergent was tested. The detergent selected as a traditional detergent from the Netherlands is in fact a compact detergent.

Liquid detergents for coloured textiles (type C)

The liquid detergents have a high rinse efficiency in general, and it appears that the detergents are rinsed out of the base load during the wash programme, especially at 30 °C. There is no real difference between the detergents.

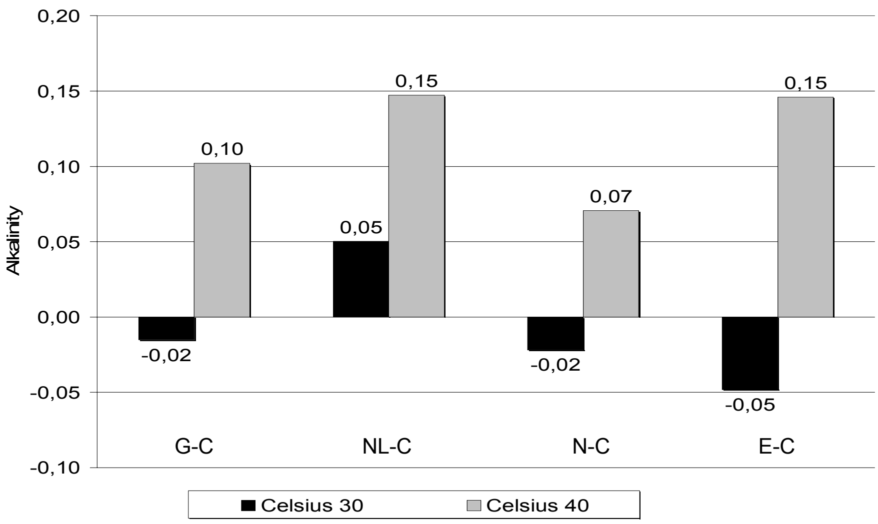

Figure 3-6 Average rinse efficiency of type C – liquid detergents for colour textiles

3.7 Conclusions

The functional performance of different laundry processes in four European countries is assessed in this research. Both wash performance and rinse efficiency are determined. The results show that Spain has better results with traditional detergents (B) at 30 °C for the wash performance, when compared to the other types of detergent tested. Greece and Spain seem to have the detergents for white textiles with highest wash performance. Both countries are known to use traditional detergents most commonly. Greece has very good results in the wash performance for the compact detergent. The traditional detergent is more widely used, but does not have the same wash performance as the compact detergent. This is in contradiction with the pattern we see in Spain, where the results clearly show that the detergents that are most used in the market also shows the highest wash performance. The most common laundry process for white textiles in Spain and Norway (respectively) seem to have about the same average value on wash performance even though the Norwegian detergent is tested using a higher wash temperature and lower water hardness. The Norwegian detergents seem to have a lower wash performance than we would expect when tested at the most common Norwegian condition. This indicates that the Norwegian detergent is not properly adapted to the common Norwegian laundry processes. Another possibility is that the dosage on the label is too low. We may conclude that Norwegians consume a lot more energy during wash than the Spanish to gain the same wash performance for their white textiles.

All the liquid detergents we tested have a significantly lower wash performance than the compact detergents tested. In fact, the wash performance when using water is similar to using the Spanish detergent. The dosage used for the Spanish detergent is quite high, and this may have caused the very bad results for this particular detergent. The low results, combined with the extremely high foam level during testing, may indicate that a different programme with less mechanical action and less programme duration is more likely to be used for this detergent in Spain. The liquid detergents from the other countries are significantly better than using just water, but in terms of wash performance alone we would advise consumers to use other types of detergents. However, with regard to rinse performance, we find that the liquid detergents have high rinse efficiency compared to the other types of detergents. This is valuable information for people with allergic reactions from residual detergent after wash.

4 Hygiene effects of laundry processes in Europe

Paul M. J. Terpstra & Inge A. C. van Kessel

4.1 Introduction

In this chapter the research on the hygienic quality of European laundering practices is described.

Until recently little attention has been paid to the hygienic properties of modern daily laundering practices. As clothes hygiene is the major benefit of laundering (apart from the removal of visible soil and stains), more insight into the hygienic implications of modern laundering practices is needed in order to design appropriate policy measures on public health and environmental policy issues.

As will be outlined in the next section, there are indications that changes in domestic laundering have substantially stressed the conditions for appropriate hygiene in the real life situation. To investigate this in detail, this part of the research is divided into two main parts: First we look at the hygienic quality at low temperatures (i.e.15°C and 30°C) in four European countries: Spain, Greece, Norway and the Netherlands. Secondly since no accurate method for assessing laundering hygiene in a real life situation exists, development of a testing method to assess the hygiene effects of the washing process for standardisation purposes is presented.

4.1.1 Theoretical background

During usage, textile articles are contaminated with visible soil and invisible micro-organisms. These micro-organisms on textiles may, under certain conditions, pose a health risk. For example if a towel is sucked by a child suffering from scarlet fever and then by a second child, the organism causing the disease can be transmitted to the second child. Many such objects (e.g. a handkerchief, a toy or a towel) may transmit infection under appropriate conditions. It should therefore be recognised that the achievement of adequate hygiene is a very important aspect of household laundering.

During textile laundering a substantial reduction in the amounts of micro-organisms can take place. In cleaning research, substantial attention is paid to disinfection and to the interrelation between cleaning and disinfection. Three main hygiene mechanisms in textile laundering are discriminated:

- *Physical removal.*

In a household washing process the main hygiene effect is probably the removal of the dirt itself; when dirt is removed well, the micro-organisms are removed with it. During the main wash cycle of a washing process the soil and the micro-organisms are suspended and the majority of micro-organisms will be drained off in one of the rinses. This mechanism is referred to as physical removal.

- *Thermal disinfection.*

In addition to physical removal, micro-organisms can be killed by heat. When suspended in the suds, micro-organisms are sensitive to temperature and chemical disinfectants and are killed easily [6]. In general a higher temperature speeds up thermal disinfection. In a laboratory study on hygiene conducted in 1989 using tests with heavy-duty detergent in a household washing machine, Ainsworth and Fletcher showed that Ent.faecalis applied on textile fabric was removed much better at 50°C than at 30°C; the difference being about 3 log units [28]. Cross-contamination was found at both temperatures but substantially more at the lower temperature. In another study carried out that same year, Ainsworth and Davis[29] showed that both for a heavy-duty powder with activated bleach and for a liquid detergent the disinfection was substantially better at 50°C than at 30°C. It should be noted that Ainsworth's investigations might yield overly optimistic values, as the tests were carried out with artificially applied test organisms. In normal laundry the organisms occur in soil aggregates that make them more persistent. The latter has been demonstrated by Terpstra [27] and Raschle [30] for the household situation. Both found substantially lower disinfection values in tests in which normally soiled laundry was used. In his research Raschle even found an increased number of bacteria after washing dirty laundry at 30°C.

- *Chemical disinfection.*
In household laundering, chemical disinfection can be achieved using various detergent bleach components. Examples of the most commonly used chemicals are tetraacetylethylenediamine/persalt combinations [4], percarbonate, perborate and sometimes dichloro-isocyanurate. Hypochlorite bleach in the last rinse of the washing process or separately after the washing process also achieves thorough disinfection.

High pH-values have a conserving effect: this means that generally, micro-organisms will not be killed but their growth will be impeded. High alkaline detergents are therefore assumed to have a positive effect on laundry hygiene. On the basis of chemical and physical theory, a strong synergistic effect between the disinfection mechanisms is assumed.

4.1.2 Approach and execution

The focus of the study is on the hygienic quality of laundry processes at low wash temperatures (i.e.15°C and 30°C) and on the two most common washing processes in four European countries. The countries were chosen such that different regional situations are represented. The hygienic levels are evaluated by assessing the microbiological counts of relevant microorganisms on naturally soiled domestic laundry before and after washing.

In a preliminary study, an inventory of micro-organisms on naturally soiled laundry is made on the basis of literature. Thereafter a set of (pathogenic) micro-organisms that may represent the hygienic quality of laundry is derived from laboratory tests. Next laundry items are chosen in which the selected micro-organisms are likely to be found. Finally the level of hygiene (i.e. the microbiological count) of naturally soiled laundry is determined before and after washing under four different conditions. For this purpose an existing test method has been refined. In addition, the level of cross-contamination between laundry items has been investigated, using original sterile textile samples. The hygienic properties of different European detergents have been assessed in separate tests. The results of the tests are compared to the results of a limited test of the level of hygiene of a real household wash.

4.2 Research design

4.2.1 Background

The hygiene effects of different laundry processes in Europe (Greece, Norway, Spain and the Netherlands) will be assessed in this research. The focus is on the hygienic quality of washing processes at low temperatures (i.e. 15°C and 30°C) and on the two most common washing processes in each country of interest.

Block et al. [5] recently developed a test method to determine the micriobicidal effect of laundry detergents within a washing process. In this test, artificially contaminated micro-organism carriers are washed together with sterile ballast fabrics in a normal washing machine under realistic conditions. After a complete washing cycle, the surviving test organisms on the carriers are identified, and cross-contamination and contamination of the washing liquid are evaluated as well. Block states that this test method is suitable for simulating realistic household laundry conditions and uses relevant test organisms.

The Block method uses artificially contaminated micro-organism carriers with high contamination levels. These high contamination levels allow for the calculation of viable reduction factors. The test organisms used are very specific and are selected with regard to their relevance to household conditions and on the basis of existing proposals.

The objective of the present study, however, is to assess the hygiene effect of a washing process and not solely to determine the micriobicidal effect of the laundry detergent. The fixation and aggregation of micro-organisms to soil particles in real life situations is quite different from the artificial contamination used by Block. Therefore, and from an even more realistic point of view, it is interesting to investigate the reduction (or cross-contamination) of micro-organisms on naturally soiled domestic laundry.

The starting point of this research design is the Block method with some major modifications. The microbiological count of relevant micro-organisms on naturally soiled domestic laundry items will be determined in a laboratory test before and after washing. The wash load is filled with a sterile cotton base load as in the Block method. The micro-organisms and laundry items are selected on the basis of a literature study and from laboratory tests. Furthermore, cross-contamination of laundry items is determined by washing sterile pieces of cotton together with the soiled items and the sterile base load. In order to get a homogeneous sample during the tests, a method for sampling is developed.

In order to validate the test method, the results of the laboratory tests are compared to the results in a normal household wash. In this test the actual hygiene situation of domestic laundry after washing is determined. Sterile samples are washed together with household laundry in a household washing machine. A good correlation between the contamination figures of both washes (laboratory wash and household wash) indicates a method that reflects the realistic household situation.

4.2.2 Test plan

Two washing programmes (15°C and 30°C) were run in a laboratory washing machine (Electrolux Wascator FOM 71MP-Lab) according to IEC 60456 [9] conditions using the most common detergents in the four European countries of interest. The only variables in this design are the type of detergent and the dosage. In this way the hygienic quality of washing at low temperatures under laboratory conditions using various European detergents and dosages can be determined.

The experimental design of the test using low temperatures is presented in table 4.1 and table 4.2.

Table 4-1 Washing at 15°C **under laboratory conditions with European detergents**

		Greece	Norway	Spain	The Netherlands
Code		GR-1	*N-1*	E-1	NL-1
Detergent		**Skip**	***Omo Color***	**Ariël Alpine**	**Ariël Color**
Type of detergent		traditional powder	tablets	traditional powder	compact powder
Bleaching agents[16]		yes	no	yes	no
Dosage	g	175	1 tab	120	70
Load	kg	4.5	4.5	4.5	4.5
Water hardness	°dH	14	14	14	14
Washing machine		Wascator	Wascator	Wascator	Wascator

The settings of the 15°C programme on the Wascator are listed in Appendix A.

[16] This refers only to the detergent. “Yes” indicates that the detergent contains a bleaching agent (e.g. an oxygen-based bleaching agent).

Table 4-2 Washing at 30°C under laboratory conditions with European detergents

		Greece	Norway	Spain	The Netherlands
Code		GR-2	N-2	E-2	NL-2
Detergent		**Skip**	***Omo TAED Plus***	**Micolor gel**	**Ariël**
Type of detergent		tablets	traditional powder	gel	compact powder
Bleaching agents[1]		no	yes	no	yes
Dosage	g	2 tabs	65	130	70
Load	kg	4.5	4.5	4.5	4.5
Water hardness	°dH	14	14	14	14
Washing machine		Wascator	Wascator	Wascator	Wascator

The settings of the 30°C programme on the Wascator are listed in Appendix B.

Additionally, the four countries were asked to supply information on their two most common laundry processes in a normal household machine.

What are the most commonly used washing programmes in each country? What type and brand of detergent is common, and what is the dosage per wash? What is the average water hardness and loading degree? With this information the actual hygienic quality in the participating European countries can be established. The two most common washing processes in each of the four European countries are listed in table 4.3. Each washing process (15°C, 30°C and the most common ones in each country) is run only once. The hygienic quality of the laundry samples is determined before and after washing.

Table 4-3 Most common washing processes in four European countries

	Greece		Norway	
Code	GR-3	GR-4	N-3	N-4
Temperature (°C)	40	60	40	60
Programme	cotton	cotton	cotton	cotton
Detergent	Skip	Skip	*Omo Color*	*Omo Ultra*
Type of detergent	tablets	traditional powder	tablets	tablets
Bleaching agents[1]	no	yes	no	yes
Dosage (g)	2 tabs	100	1 tab	1 tab
Load (kg)	5	5	3.5	3.5
Water hardness (°dH)	15.4	15.4	3.5	3.5

Table 4-3 Continued

	Spain		The Netherlands	
Code	E-3	E-4	NL-3	NL-4
Temperature (°C)	15	40	40	60
Programme	delicate	cotton	cotton	cotton
Detergent	Ariël Alpine	Ariël Alpine	Ariël Color	Ariël
Type of detergent	traditional powder	traditional powder	compact powder	compact powder
Bleaching agents[1]	yes	yes	no	yes
Dosage (g)	120	120	65	65
Load (kg)	3	3	3.3 kg	3.3 kg
Water hardness (°dH)	9	9	9	9

All cycles are run in a Miele W362 household washing machine.

4.3 Selection of Microorganisms and laundry items

4.3.1 Literature

There are only a handful of experts on this subject, and their scope is often considerably broader than the objective of this research. In most studies a relationship between kitchen hygiene and food poisoning is established. Literature on the hygiene effects of domestic laundry processes has not been found.

In a bacteriological survey of the domestic environment, Finch [1] sampled various surfaces in the kitchen, bathroom, living room and hall of 21 homes. In more than half of the dishcloth, towel and teacloth samples, coagulase negative Micrococcaceae and *Bacillus* spp. were present. Various bacteria were found on the dishcloth, and *Staphylococcus aureus* was present on half of the towel and teacloth samples. Later Speirs [2] did a similar study in 46 homes. Speirs found different Enterobacteria, *Pseudomonas*, *Bacillus* and *Staphylococcus aureus*. More than 90% of the sampled tea and hand towels and more than 94% of the sampled dishcloths had counts of >450 CFUs per area (approximately $25cm^2$). This represents a contamination hazard.

Scott [3] showed that *Escherichia coli*, *Salmonella spp.*, *Klebsiella aerogenes* and *Staphylococcus aureus* survive on clean and soiled cloth and that they are easily transferred via cloths, hands and utensils. The survival rate on clean cloth was less than on soiled cloth, but in both cases regrowth was shown. Drying the cloth increased the number of bacteria. In a laboratory wash test using different kinds of disinfectants, Scott [4] also showed that the initial counts of a three-day-old used dishcloth varied from $1.7*10^2$ to $2.5*10^6$ CFU/cm^2. The Total Plate Count increased after washing or disinfecting the samples. Regrowth after storage was observed.

Block [5] demonstrated that detergents containing a TAED-activated bleach will not disinfect clothes when they are washed at 20°C or 30°C. This might be due to the pH differences in the suds, as Betz [7] discovered while investigating the anti-microbicidal effects of different bleaching agents at low washing temperatures. Betz added different bleaching agents to a buffered bacteria culture at 30°C and 40°C. Reductions of *Enterococcus feacium* of log 2 to log 7 were found, depending on the bleaching agents that were used.

The washing temperature seems to be even more important. Walter [6] conducted a study with used hospital and student bed linens. These linens were inoculated with *Staphylococcus aureus* and *Klebsiella pneumoniae* and washed at different temperatures. *Klebsiella pneumoniae* was easily washed out, but only after washing for 13 minutes at 60°C was *Staphylococcus aureus* no longer detectable. A wash heat exposure time of 8 minutes or a temperature of 54°C was not sufficient to remove all the *Staphylococcus aureus*.

4.3.2 Selection of Micro-organisms

Several micro-organisms were selected for the test (based on the literature study) consisting of a mixture of different groups of micro-organisms and one specific one. The selected micro-organisms are known to be found on laundry. They are pathogenic or members in their group are pathogenic. Last but not least, the detection of these micro-organisms must be practical and feasible.

Enterobacteriaceae

Enterobacteriaceae are a very common family of bacteria with a few harmful members such as the *Salmonella* group. *Salmonella* is reported as one of the most common causes of food poisoning. Enterobacteriaceae are found everywhere and are easy to culture. They are often used as an indicator of hygiene conditions. Finch [1] and Speirs [2] found Enterobacteriaceae on soiled dishcloth, tea towels and hand towels. Scott [3] and Block [5] also did research with cultures of this group of micro- organisms.

Bacillus

Bacillus are another common group of bacteria. *Bacillus cereus* is the pathogen in this group. It is not only known to cause food poisoning by producing a toxin in cooked food; it can also cause food borne infection. *Bacillus cereus* is particularly dangerous because it is a spore-bearing bacterium. A spore is a resting body, which is produced when conditions are unfavourable for growth and particularly when there is a lack of moisture. The spores can survive in a dormant condition for long periods of time under adverse conditions, but when suitable conditions of food, moisture and temperature return they are able to germinate into actively growing bacteria again. In the studies of Finch [1] and Speirs [2], *Bacilli* were found on soiled dishcloths, tea towels and hand towels. Betz [7] used a culture of *Bacillus subtilis* for his test.

Staphylococcus aureus

Staphylococcus aureus is reported as the most important cause of food poisoning. 50% of all people carry this bacteria in their nose and/or around the anus. *Staphylococcus aureus* is spread easily by contaminated hands, utensils etc. Again, Finch [1] and Speirs [2] found *Staphylococcus aureus* on soiled dishcloths, tea towels and hand towels. Most of the work of Walter [6] and part of the studies by Scott [3] [4] were based on artificial contamination with *Staphylococcus aureus*.

Yeasts and Fungi

Yeasts and fungi are found everywhere. Spores can survive dry conditions but for the most part yeast and fungi are found in damp conditions. Only Block [5] used a yeast culture in his study. Other studies focussing on yeasts and fungi were not found.

Total Plate Count

The Total Plate Count gives an idea of the overall effect of washing. There are many different bacteria present in laundry. Using Total Plate Count almost every bacterium present in the laundry will be detected.

4.3.3 Selection of Laundry Items

In order to find the selected micro-organisms, laundry items have to be selected. In this experiment the hygienic condition of naturally soiled laundry is assessed. However, it was not possible to collect dirty laundry from different households because of the heterogenic composition in time. For the purpose of the test, only a few laundry items on which the selected micro-organisms are likely to be found were selected.

The occurrence and amount of micro-organisms on the selected laundry items was determined in a pre-test for verification purposes.

Handkerchief

Because 50% of the human population are carriers of *Staphylococcus aureus* in the nose, a handkerchief of a carrier was selected. The average amount of *Staphylococcus aureus* found on a used handkerchief was log 3.3 CFU/3 cm^2.

Diaper

Faeces are full of bacteria; Enterobacteriaceae, *Bacillus* and in many cases *Staphylococcus aureus* are very likely to be found. A baby's diaper could be a good sample for finding these micro-organisms. All bacteria were confirmed on the diapers in the pre-test. The average diaper contains about log 5.9 CFU/3 cm^2 Enterobacteriaceae, log 5.6 CFU/3 cm^2 *Bacillus* and 4.0 CFU/3 cm^2 *Staphylococcus aureus.*

Socks

Many people have foot moulds. A pair of socks could be contaminated with this micro- organism. Socks are also worn in a damp environment as a shoe. These are the ideal conditions for growing yeasts and fungi. Only one log unit CFU/3 cm^2 was found in the pre-test.

Dishcloth

Previous studies ([1], [2]) show that a dishcloth is a very highly contaminated piece of laundry. It contains a mix of various bacteria found in almost every household. It can contain every micro-organism which is investigated in this experiment. This was confirmed during the pre-test (see table 4-4).

4.3.4 Laundry items

The laundry items used are listed in table 4-5. All items are naturally soiled by being used or worn by members of a private household. Each laundry item is used by the same (member of a) household during the experiment. In this way the contamination of the laundry items during the experiment is as identical as possible. To evaluate cross-contamination, sterile samples are used. The fabric is 100% cotton. The samples are autoclaved for 15 minutes at 121°C.

Table 4-4 Laundry items

Laundry item	Textile material	Fabric	Brand
Diaper	100% cotton	woven	Hema
Dishcloth	100% cotton	non-woven	Albert Heijn
Socks	61% cotton, 35% polyester, 4% elastan	knitted	Hema
Handkerchief	100% cotton	woven	Hema

4.3.5 Sampling

Micro-organisms are not evenly spread on the laundry items. In order to obtain a more homogenous sample, a paper shredder is used to cut the items into small pieces (see also photo 4.1). The paper shredder is disinfected with alcohol (70%) and the small pieces are collected in a sterile bag. After mixing, 30 of these pieces are used as a sample for determining the amount of micro-organisms before washing. Additionally, 30 pieces are put in a sterile washing bag (a bag used for washing tabs) and used for the assessment of the hygienic quality after washing. The samples are kept for a maximum of three days in the refrigerator.

Picture 4-1 Sampling



4.3.6 Washing

The washing machine is loaded with a gamma sterilised cotton base load. The composition of the base load is in accordance with IEC 60456 [9]. The washing bags with laundry samples (a sample of each laundry item is put in a separate washing bag) and the washing bag with the sterile samples are added to the wash load. Direct contact between the washing bags is avoided. A per kilogram base load of 12.5 ml defibrinated sheep blood (Biotrading) is added to increase the soil level. The load weight, washing programme, washing temperature, water hardness and detergent used depend on the test.

4.3.7 Enumeration and confirmation of micro-organisms

All samples are directly removed from the machine and put in a sterile stomacher bag at the end of the washing process. 50 ml of a buffered peptone solution (Oxoid, CM509) with a temperature of 30°C is then added. After 5 minutes, the bag is stomachered for 30 seconds. The obtained solution is diluted in PFZ (Biotrading, K110B009) and used for enumeration. The same procedure is used for the enumeration and confirmation of micro-organisms in the dirty laundry samples.

<u>Enumeration of Enterobacteriaceae</u>
1 ml of the serial dilution is transferred to a plate and mixed with ca. 10 ml Violet Red Bile Glucose Agar (VRBGA) (Lab M LAB88). After solidification of the agar, a topcoat is added using the same medium. The plates are incubated for 20-24h at 37°C. Suspected Enterobacteriaceae colonies are counted after the incubation period. Confirmation is done by testing the presence of oxidase (Bactidrop, Oxidase test R21540). Enterobacteriaceae are purple colonies surrounded by a zone of purple precipitation and are oxidase negative.

<u>Enumeration of Staphylococcus aureus</u>
0.1ml of the serial dilution is spread on a Baird Parker (BP) plate (Biotrading, K002P090) and incubated for two days at 37°C. Black, shiny colonies with a halo were counted.

<u>Enumeration of Bacilli</u>
0.1ml of the serial dilution is spread on a MYP/PREP plate (Biotrading, K104P090) and incubated for one day at 30°C.

Bacillus cereus colonies are pink and surrounded by a zone of precipitation. Suspected colonies are plated on MYP/PREP and again incubated for one day at 30°C. The result is considered positive if the colonies are pink and surrounded by a zone of precipitation. It is also possible to see *Enterococcus faecalis* on these plates. These colonies are yellow, glossy and sized 0.5mm.

Enumeration of the Total Plate Count
1 ml of the serial dilution is transferred to a plate and mixed with ca 15ml PCA (Plate-Count-Agar, Merck, 5463). The plates are incubated for three days at 30°C. Every visible colony on this plate is counted.

Enumeration of yeast and fungi
0.1ml of the serial dilution is spread on an OGGA-plate (Biotrading K1042090) and incubated for 5-7 days at 25°C. During this period the plates are checked on the third day and the yeasts are counted. This is done in order to see the yeasts before they are overgrown by fungi.

4.3.8 Calculation

The number of micro-organisms is calculated according to normal microbiological rules.

$$N = \frac{\sum a}{(n_1 + 0{,}1 n_2) d}$$

N	= number of colonies
Σa	= sum of the number of counted colonies
n_1	= number of plates in first dilution
n_2	= number of plates in second dilution (less diluted)
d	= dilution rate corresponding first dilution

Plates with one or two colonies are considered negative, as these findings might be due to cross-contamination during the test. A negative result is written as <3, or in log scale <0.5 CFU/4.7cm^2.

All results are shown in logarithmic values.

4.4 Results

In this chapter, the results of the assessment of the hygienic quality (i.e. the microbiological count) of naturally soiled laundry will be presented before and after washing for four different European countries. Most results are graphically depicted in bar charts where a comparison of the microbiological count before washing and after washing is made. The X-axis indicates the wash temperature and the situation before washing. The Y-axis gives the logarithmic microbiological count per 4.7 cm^2.

4.4.1 Washing at low temperatures

The results of the microbiological counts for the 15°C and 30°C programme are shown in graphs 4.1 and 4.2. The colony counts are summarised in appendixes C and D. The data have been statistically analysed. In the analysis, for practical reasons it is assumed that the data values <0.5 and <1.5 (detection limits) and <2.5 (not countable due to non-specific growth) are all considered equal to zero. Before washing, no significant difference between the samples was found (ANOVA-One Way, $\alpha = 0.05$). We are certain with a 95% level of confidence that the microbiological counts of the different laundry items are all equal before washing.

European detergents at 15°C

A significant difference is found between before and after washing (ANOVA-One Way, $\alpha = 0.05$) for all micro-organisms. Laundry is hygienically cleaner after washing, although graph 5.1 shows that, from a microbiological point of view, the hygiene level is barely improved. For example, the Total Plate Count after washing varies between 3.6 and 8.0 log units. This means that on a sample of 4.7 cm^2 between 4000 and 10^8 micro-organisms were found. About 4 to 5 log units were found on the sterile samples.

No differences were found between the different countries. The hygiene situations in the four different countries are more or less equivalent, not only for the Total Plate Count but also for all micro-organisms in the test.

The Total Plate Count gives an impression of the overall hygienie situation. When investigating specific groups of micro-organisms, for example the Enterobacteriaceae, some interesting phenomena emerge. Only the diaper and dishcloth were contaminated with Enterobacteriaceae before washing. After washing, these bacteria were found on each laundry items and on the sterile samples (figure 4.2). The washing process is spreading micro-organisms instead of removing them. This is also the case with *Staphylococcus aureus* [17]

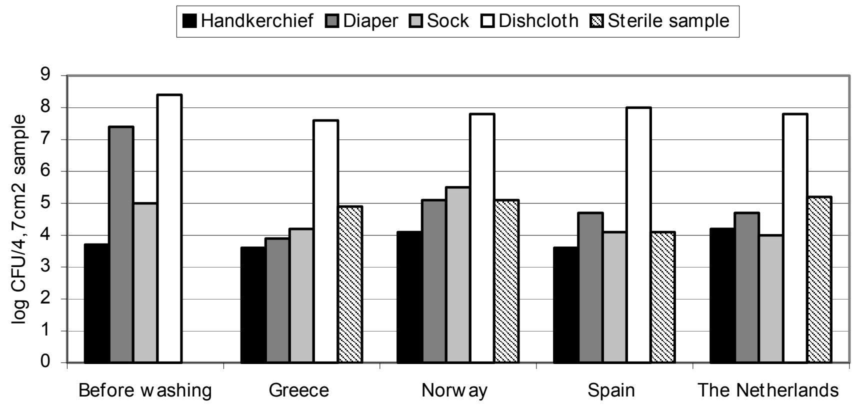

Figure 4-1 Total plate count before and after washing at 15 C

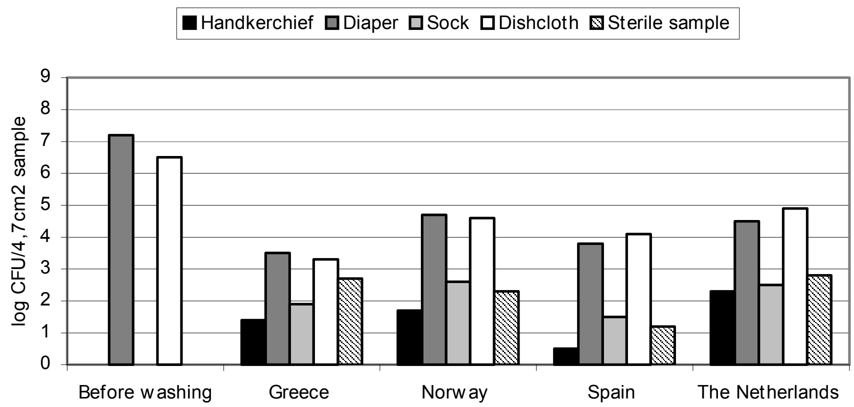

Figure 4-2 Enterobacteriaceae before and after washing at 15 C

The Total Plate Count gives an impression of the overall hygienie situation. When investigating specific groups of micro-organisms, for example the En-

[17] Further details to be found in WUR project publication.[22]

terobacteriaceae, some interesting phenomena emerge. Only the diaper and dishcloth were contaminated with Enterobacteriaceae before washing. After washing, these bacteria were found on each laundry items and on the sterile samples (figure 4.2). The washing process is spreading micro-organisms instead of removing them. This is also the case with *Staphylococcus aureus* [18]

The cross-contamination of the sterile sample also gives a good impression of the spreading of micro-organisms. All sterile samples are contaminated (see also graph 5.3). With the exception of fungi, all micro-organisms are spread throughout the washing process.

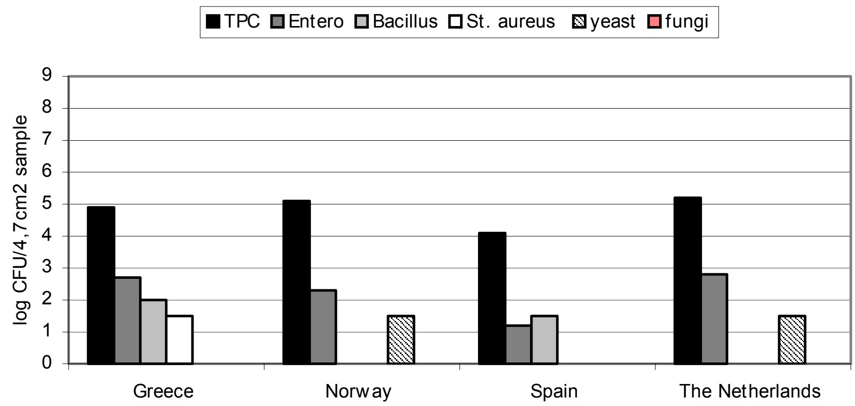

Figure 4-3 Cross-contamination of sterile samples at 15°C

European detergents at 30°C

A significant difference is found between before and after washing (ANOVA-One Way, $\alpha = 0.05$). Laundry is hygienically cleaner after washing. Although the microbiological count at 30°C is lower than at 15°C, the hygiene level is rather low. The Total Plate Count after washing varies between 2.7 and 7.1 log units, which means that on a sample of 4.7 cm^2 between 500 and 10^7 micro-organisms were found (graph 4.4). About 4 log units were found on the sterile samples (graph 4.6).

[18] Further details to be found in WUR project publication.[22]

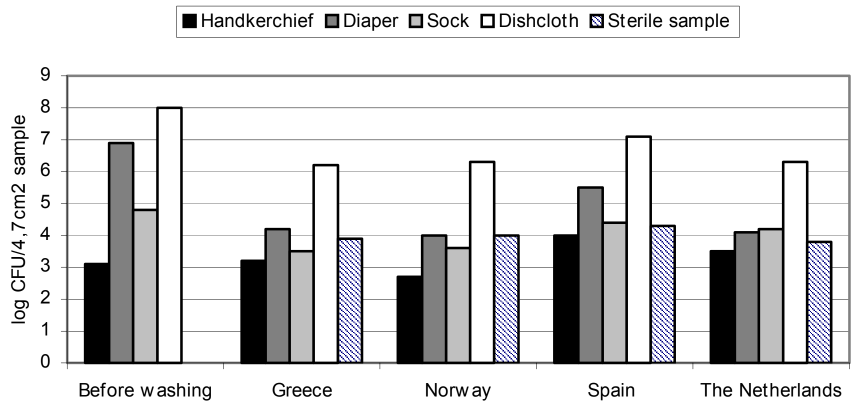

Figure 4-4 Total plate count before and after washing at 30°C

In accordance with washing at 15°C, no differences between the countries were found (ANOVA-One Way, $\alpha = 0.05$).

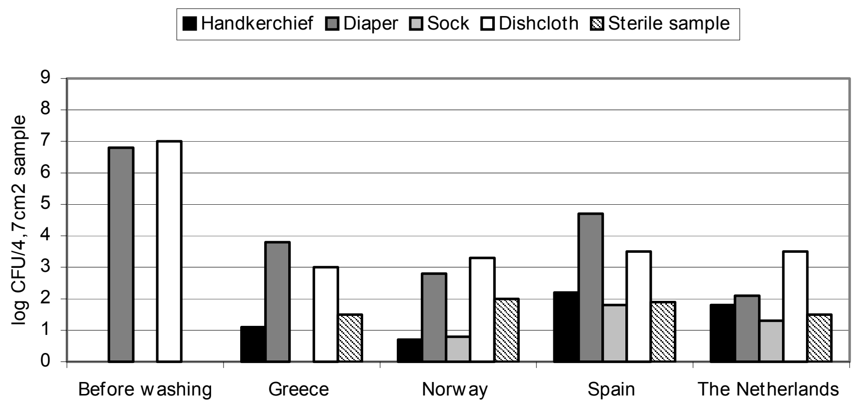

Figure 4-5 Enterobacteriaeae before and after washing at 30°C

Again it is clear that Enterobacteriaceae are spread around by the washing process (see graph 4.5). Although a reduction of 2 - 4.5 log units for the diaper and 3.5 - 4 log units for the dishcloth has been established, after washing these bacteria also found on the handkerchief, the sock and the sterile sample. The spread of the Enterobacteriaceae also becomes clear in graph 4.6. All sterile samples were contaminated with Enterobacteriaceae and had a high

Total Plate Count. In most cases, *Bacilli* and *Staphylococcus aureus* had been removed from the laundry items during washing, and no cross-contamination on sterile samples was found either.

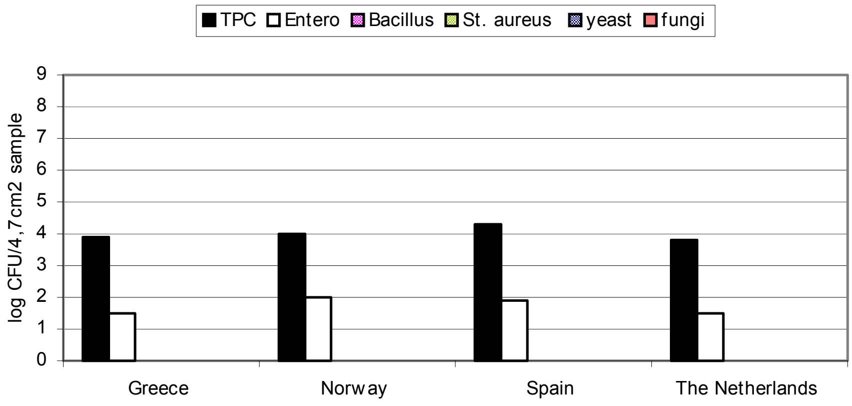

Figure 4-6 Cross-contamination of sterile samples at 30°C

Hygienic quality of washing at lower temperatures

The results show that the hygienic quality of the washing processes at low temperatures (i.e. 15°C and 30°C) leaves something to be desired. A small reduction of the Total Plate Count is achieved only in some cases. The contamination level after washing is still relatively high. A significant temperature effect on the hygienic quality is found (ANOVA-One Way, $\alpha = 0.05$): from a hygienic point of view a 30°C washing process is better than a 15°C washing process. There is no effect of the bleaching agent on the hygienic quality. The hygienic properties of the detergents in the dosages used have the same level in the four European countries. No significant differences were found at 15°C and at 30°C.

4.4.2 The most common washing processes in the actual countries

Greece

The two most common washing processes in Greece are a 40°C cotton programme with a detergent (tablets) without bleaching agents and a 60°C cotton programme with a traditional powder containing bleach. The most interesting results are summarised in graphs 4.7 and 4.8. A significant difference is found between before and after washing (ANOVA-One Way, $\alpha = 0.05$): the laundry is hygienically cleaner after washing. The overall hygienic quality of the 60°C programme is better than the quality of the 40°C programme (ANOVA-One Way, $\alpha = 0.05$). There is a reduction of about 2 log units in the Total Plate Count between the two processes.

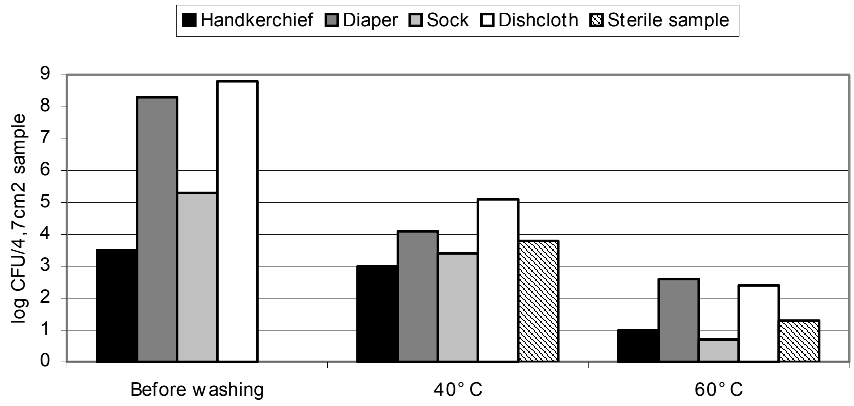

Figure 4-7 Total Plate count of the most common Greek washing processes

All Enterobacteriaceae were removed by the 60°C washing process. Using the 40°C process, the reduction on the diaper and the dishcloth is obvious, but the bacteria are again spread throughout the washing machine. The result was about the same for *Staphylococcus aureus*. The 60°C washing process removes all bacteria, whereas the 40°C process spreads them around. No *Bacilli* or fungi were found after washing at both 40°C and 60°C and the amounts of yeast were very low.

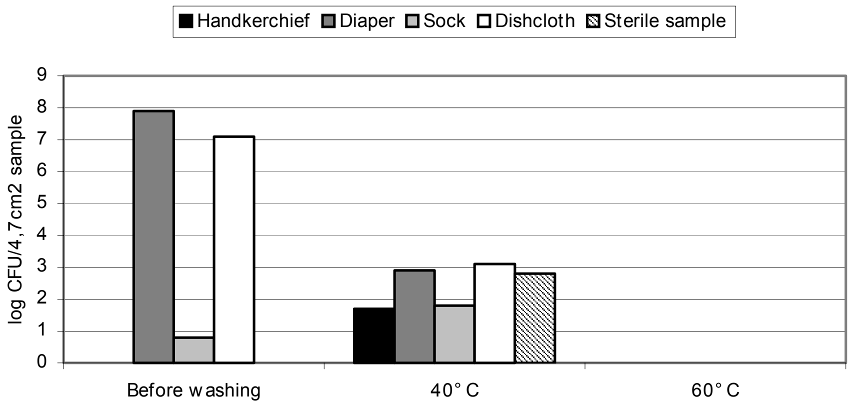

Figure 4-8Enterobacteriaceae in the most common Greek washing processes

Norway

The two most common washing processes in Norway are a 40°C cotton programme with a detergent (tablets) without bleaching agents and a 60°C cotton programme with a detergent (tablets) containing bleach. The colony counts of these processes are presented in Appendix F. The most interesting results are summarised in graphs 4.9 and 4.10.

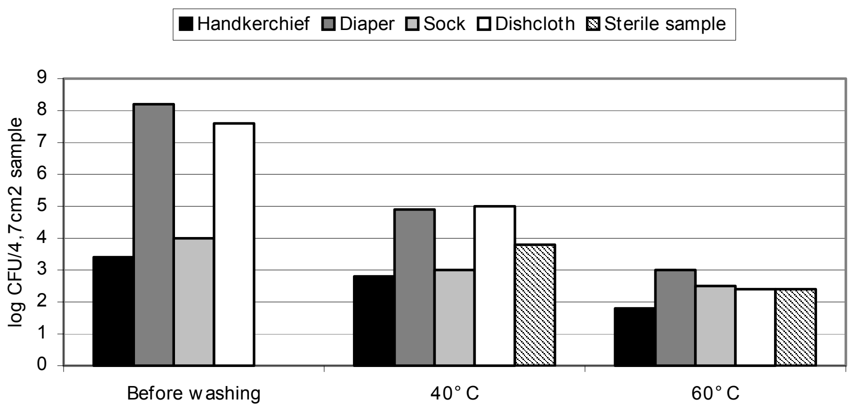

Figure 4-9 Total Plate Count of the most common Norwegian washing processes

No significant difference is found between the Total Plate Count before washing and after the 40°C programme. A significant difference is found between the Total Plate Count of the 40°C programme and the 60°C programme (ANOVA-One Way, $\alpha = 0.05$). The hygienic quality of the 60°C programme is better. Almost all Enterobacteriaceae were removed by the 60°C washing process (graph 4.10). A reduction of about 3 log units is achieved by the 40°C process on the diaper and the dishcloth. Again it is clear that bacteria are spread throughout the washing machine. Hardly any *Staphylococcus aureus*, yeasts or fungi were found after washing both at 40°C and at 60°C and the amounts of *Bacilli* were very low.

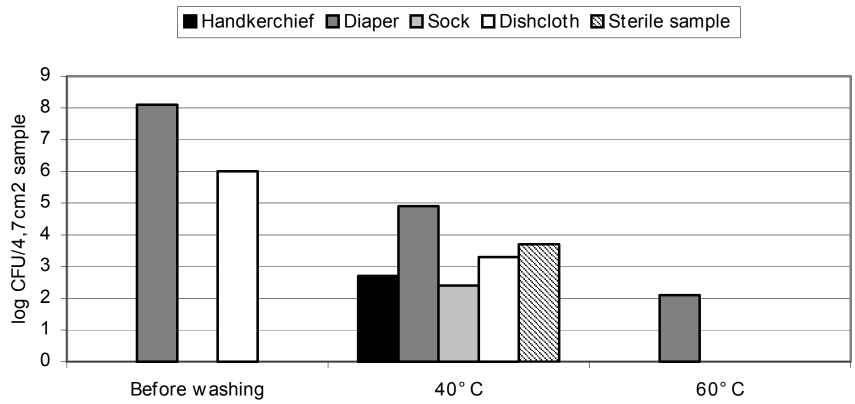

Figure 4-10 Enterobacteriaceae in the most common Norwegian washing processes

Spain

The situation in Spain is somewhat different from most other European countries. The washing temperature in Spain is relatively low. The two most common washing processes in Spain are 15°C and 40°C cotton programmes, both with a traditional powder containing bleaching agents. The 15°C cotton programme is not available on household washing machines in Northern European countries. Therefore, instead of a cotton programme, a delicate programme is used. The most interesting results are summarised in graphs 4.11 and 4.12.

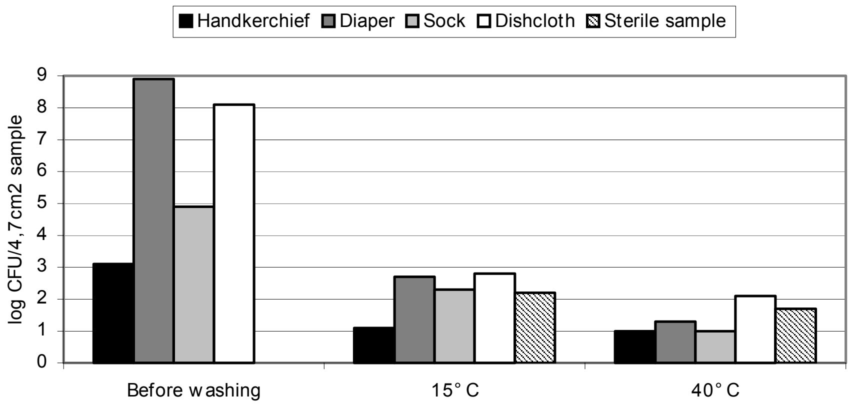

Figure 4-11 Total Plate Count of the most common Spanish washing processes

The Spanish washing processes show some interesting results. A significant reduction of the Total Plate Count at 40°C is established (see graph 4.11). Even at 15°C the amount of micro-organisms is relatively low. No significant differences were found between the 15°C and the 40°C programmes. Even more interesting are the results shown in graph 4.12. All Enterobacteriaceae are removed from the laundry items. Only after the 15°C programme is the sterile sample slightly contaminated (0.7 log units).

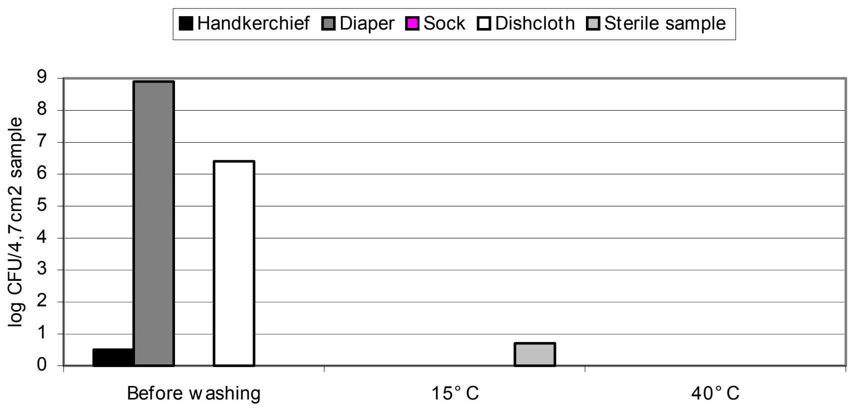

Figure 4-12 Enterobacteriaceae in the most common Spanish washing processes

No *Bacillus* and no *Staphylococcus aureus* were found after washing and hardly any yeasts or fungi were found.

The Netherlands

The two most common washing processes in the Netherlands are a 40°C cotton programme using a compact powder without bleach and a 60°C cotton programme also using a compact powder but with bleaching agents. The most interesting results are summarised in graphs 4.13, 4.14 and 4.15. A significant difference is found between before and after washing (ANOVA-One Way, $\alpha = 0.05$): the laundry is hygienically cleaner after washing. The Total Plate Count of the Dutch washing processes is comparable to the situation in Greece and Norway. In the Netherlands, a significant difference is found between the 40°C and the 60°C programme (ANOVA/One Way, $\alpha = 0$). The spread of micro-organisms is shown in graph 4.14. Before washing, the Enterobacteriaceae were found only on the diaper and the dishcloth, but after washing at 40°C they were found on all laundry items including the sterile sample. The 60°C programme, however, removed all Enterobacteriaceae.

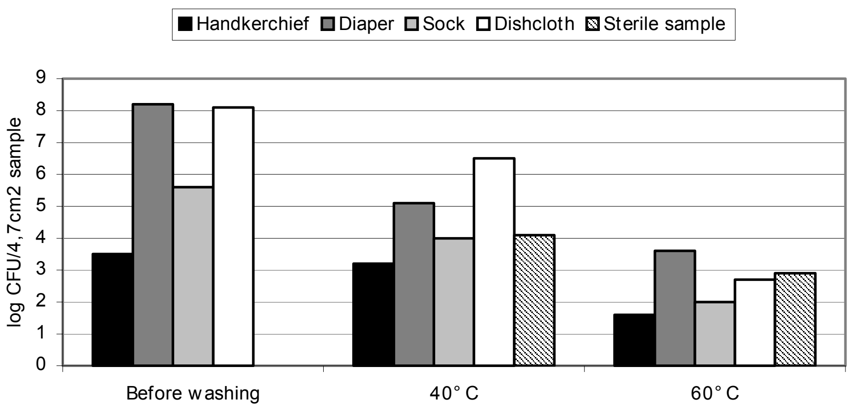

Figure 4-13 Total Plate Count of the ost common Dutch washing processes

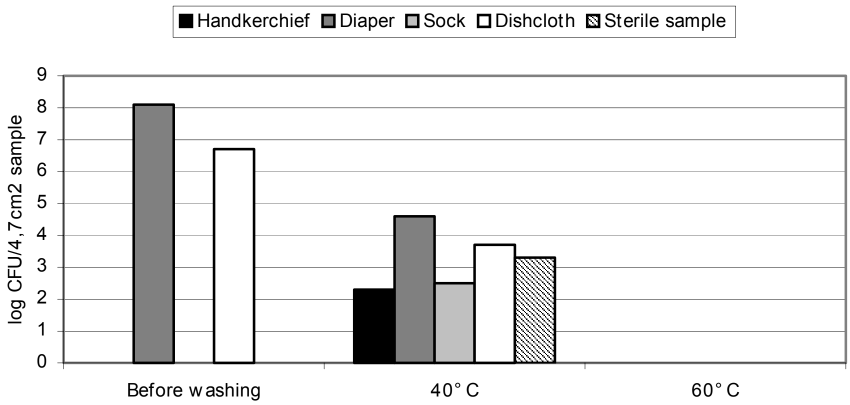

Figure 4-14 Enterobacteriaceae in the most common Dutch washing processes

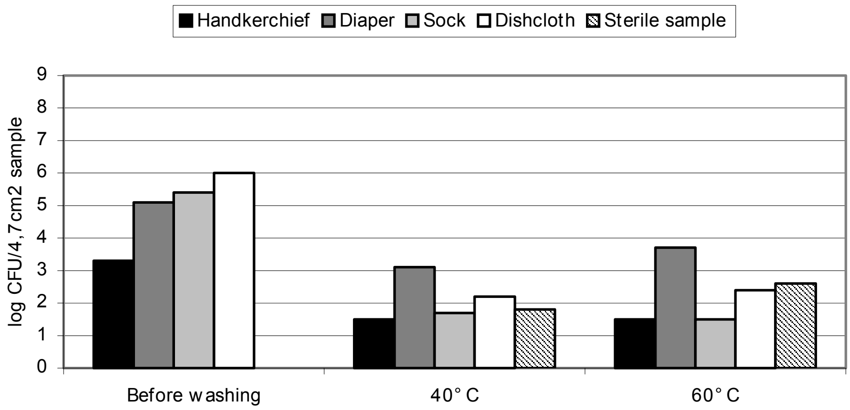

Figure 4-15 Bacilli in the most common Dutch washing processes

Some interesting results also appear for the *Bacilli* (graph 4.15). The amount of *Bacilli* after the Dutch washing processes is relatively high. Even the 60°C programme did not remove these micro-organisms and the contamination level of the sterile sample is even higher than at 40°C. No significant differences were found between these washing programmes. Similar results for the amount of *Bacilli* were found only in Norway. The Greek and Spanish washing processes removed all *Bacilli*. An additional analysis of the micro-organisms on the laundry samples showed that the diaper samples in the Norwegian and Dutch tests were contaminated with *Bacillus cereus*, a pathogenic micro-organism known to cause food poisoning or food borne infection. *Bacillus cereus* was found in all other laundry items after washing. Again these results indicate that washing does not remove micro-organisms, but is rather a process of spreading them around. Bacillus cereus survived not only the 40°C programme, but also washing at 60°C. It is to be expected that these bacteria would also survive at lower temperatures.

4.4.3 Cross-contamination

Cross-contamination of the sterile samples in each country is depicted in graph 4.16. In general, the cross-contamination of the sterile samples in the 60°C programmes tends to be lower than in the 40°C programme. However, the situation in Spain is completely different from the other countries. The contamination level in Spain is relatively low.

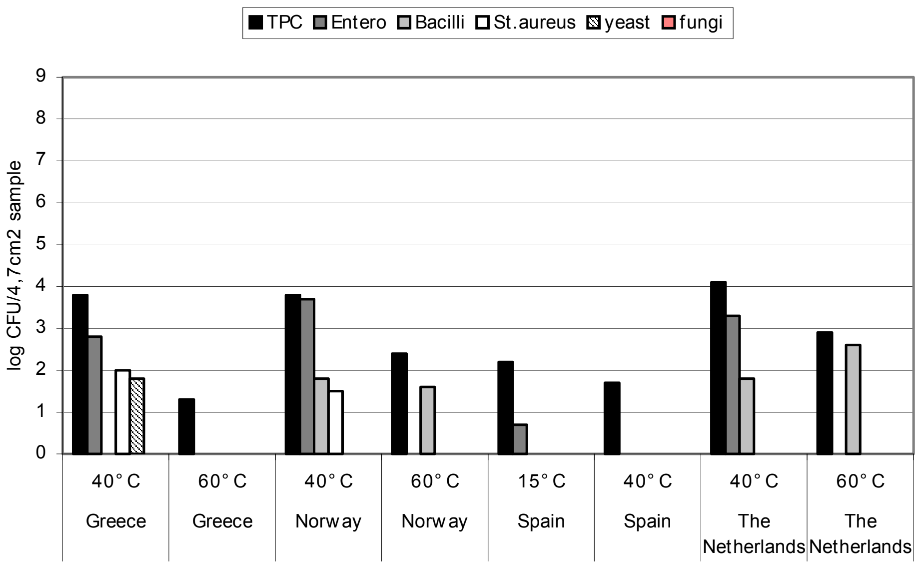

Figure 4-16 Cross-contamination of the sterile samples

When the contamination level of the 15°C programme is compared to the same programme in the Wascator, some interesting results appear. The contamination levels differ more than expected. This is also the case on all other laundry samples (see graph 4.17). A systematically higher colony count of about 2 log units was found with the Wascator. The difference is even greater for the dishcloth.

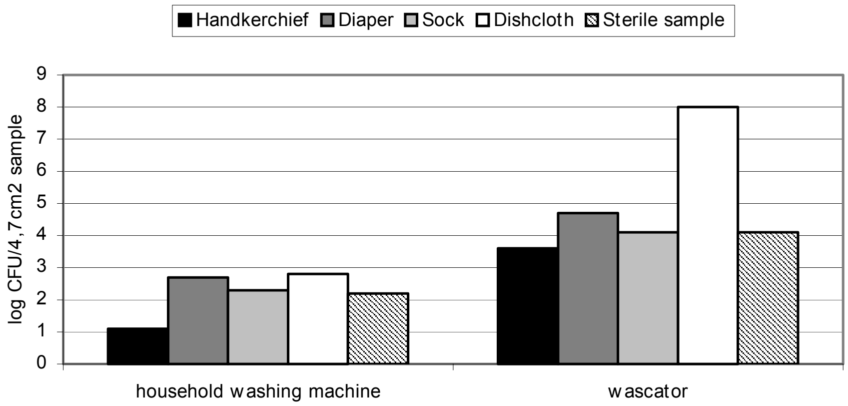

Figure 4-17 Total Plate count of the 15°C in Spain

To verify the results of the Spanish test, the 15°C and 40°C tests were repeated. The test confirmed the earlier results but brought another aspect to light. The Spanish detergent generated a lot of foam during the washing process. The Miele Novotronic W362 household washing machine automatically adds an extra rinse if extensive foam is detected. It is also known that the water consumption of the Wascator is less than in a normal household washing machine. Water consumption could not only be an explanation for the differences between the household washing machine and the Wascator, but could also explain the differences in the Spanish results from the other European countries. Extra rinses occurred only during the Spanish test. To test this hypothesis, another test was performed. A normal 40°C cotton programme with a compact detergent was compared to the same programme with an extra rinse. Graph 4.18 depicts the most interesting findings. The results show that an extra rinse improves the hygienic quality by more than 1 log unit. Although the differences between the Spanish results and the results in other European countries are greater than 1 log unit, it could very well be one of the possible explanations for the deviating results. At this time other explanations were not found.

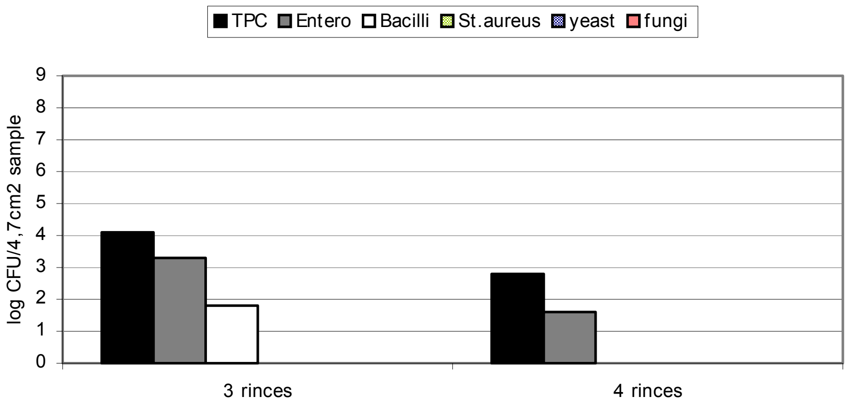

Figure 4-18 Effect on the contamination level of the sterile samples of an extra rinse in a 40°C programme

4.4.4 Hygienic quality

As far as the most common washing processes are concerned, the situations in Greece, Norway and the Netherlands are more or less comparable. This is confirmed by the results: the hygienic quality of these washing processes is very much alike (see graph 4.19). The results from the Spanish washing processes seem to be very different from the other European countries. However, a significant difference could only be found between the Dutch and the Spanish washing processes (ANOVA-One Way, $\alpha = 0.05$). In all other instances, no significant differences between countries were found.

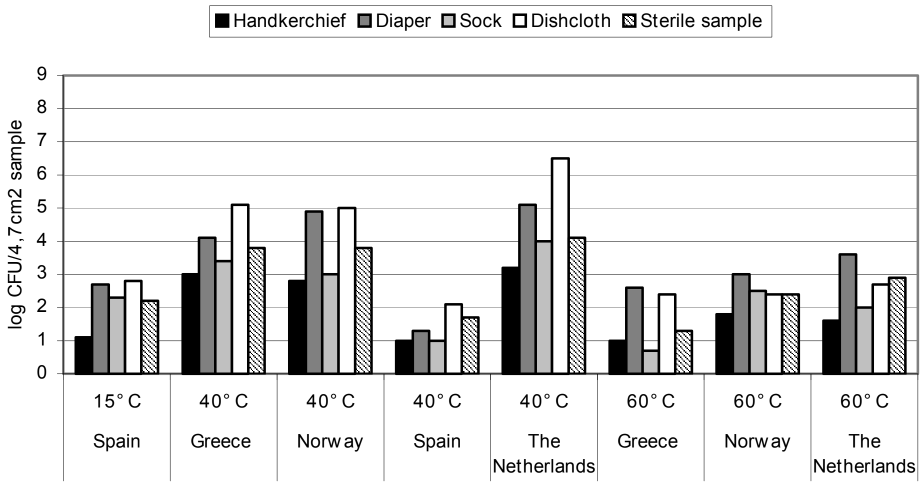

Figure 4-19 Total Plate Count

A significant temperature effect on the hygienic quality is found (ANOVA-One Way, $\alpha = 0.05$) between the 15°C and 40°C programmes and between the 40°C and 60°C programmes. In general, the hygienic quality is better when the washing temperature is increased from 40°C to 60°C. The deviating Spanish results could be explained by the higher water consumption. Furthermore, a significant effect of bleach on the hygienic quality of laundry is found (ANOVA-One Way, $\alpha = 0.05$). The hygienic quality improves when detergents with bleaching agents are used. This is also confirmed by an additional test at 60°C without bleaching agents. The hygienic quality was lower than when bleaching agents were used. The effects of temperature and bleach interact. When a detergent contains bleach and the washing temperature is increased, the hygiene result improves.

4.5 Repeatability and validation

The hygienic quality of common washing processes on naturally soiled laundry is assessed in the previous chapters according to a newly developed testing method. The focus in this chapter is on the repeatability and validation of this method.

4.5.1 Repeatability

If the samples are treated in a similar way in a series of independent tests, will they yield the same results? The repeatability of the testing method is evaluated using two laundry samples, a dishcloth and a diaper, and a sterile sample in a 40°C cotton programme. These laundry samples are chosen because of their relatively high numbers of CFU in previous tests. The samples are only tested for the Total Plate Count, Enterobacteriaceae and *Bacilli*.

The test is repeated five times in two identical household washing machines (Miele Novotronic W362). The dishcloth and diaper were sampled according the method described in 4.4. One sample of the dishcloth, one sample of the diaper and a sterile sample were washed in each was cycle with 3.3kg gamma sterilised laundry at 40°C. twelve and one-half ml defibrinated sheep blood (Biotrading) was added per kg laundry to increase the soil level. The water hardness was 9°dH and 52g Ariel Color (compact detergent without bleaching agents) was added into the dispenser. The samples were collected and the micro-organisms were enumerated after washing. The results are presented in table 4-6 The Petri dish from one of the sterile samples (run 5) was contaminated; thus, the logarithmic count is not available. The other logarithmic counts are very much in line with each other. The maximum difference between the runs is about 1 log unit.

Table 4-5 Results of the repetitions of the test method at 40°C [logarithmic count of CFU in 4.7 cm2 sample]

	run 1	run 2	run 3	run 4	run 5
Total Plate Count					
Diaper	4.2	3.9	4.6	3.9	4.0
Dishcloth	6.4	6.0	6.1	5.7	5.6
Sterile sample	4.1	4.0	4.2	4.2	3.9
Enterobacteriaceae					
Diaper	2.8	2.5	3.3	2.6	2.9
Dishcloth	4.3	3.8	4.0	3.8	4.3
Sterile sample	2.7	2.6	2.6	2.0	2.8
Bacillus					
Diaper	4.1	3.8	4.4	3.6	3.9
Dishcloth	2.4	1.3	1.9	1.5	1.6
Sterile sample	3.7	3.6	3.7	2.5	n/a

Statistic analysis did not show any significant differences between the five runs (ANOVA-One Way, $\alpha = 0.05$). Therefore, the method seems to be repeatable.

4.5.2 Validation

As table 4-6 shows, the newly developed test method is repeatable. Another relevant question is whether the test reflects common daily household practice. Therefore the results of the laboratory tests are compared to the results of a microbiological count of a normal household wash. Several private Dutch households were asked to bring their every day dirty laundry to the laboratory. It had to be laundry that they would normally wash in a 60°C cotton programme. The 60°C programme is used in the Netherlands for washing underwear, dishcloths etc. These laundry items were also selected for the laboratory tests and were washed at 40°C. In this way the results are readily comparable. The same household washing machines were used for this test as in the previous laboratory tests. A 95 °C cotton cycle was run in advance to reduce background microflora. The members of the households were instructed to load the washing machine in a way they normally would. They were asked to bring their own detergent and to use the dosage they would normally use. A 40°C or 60°C cotton programme was used. A sterile sample was added to each process. After washing, this sample was collected and enumerated for the Total Plate Count, Enterobacteriaceae, *Bacilli* and *Staphylococcus aureus*. The results of the colony counts are compared to the average test results from the laboratory tests. These results are presented in table 4.7 and table 4.8. The washes from the households are labelled wash A, wash B, etc.

Table 4-6 Hygienic quality of sterile samples after washing at 40°C [logarithmic count of CFU in 4.7 cm2 sample]

	average results-laboratory tests	wash A	wash B	wash C	wash D	wash E
Total Plate Count	3.9	4.5	3.5	4.1	3.3	5.4
Enterobacteriaceae	3.3	<0.5	<0.5	0.5	0.5	1.8
Bacillus	1.2	3.4	3.7	<1.5	2.1	4.3
St. aureus	1.5	2.2	1.9	2.6	<1.5	2.7

A detergent without bleaching agents was used for all household washes. The average results of the laboratory test are based on the tests at 40°C from Greece, Norway and the Netherlands. A detergent without bleaching agents was used in all cases. In daily practice, the amount of Enterobacteriaceae after washing is considerably lower than in laboratory tests. Hardly any Enterobacteriaceae were found in four out of five washes. The colony count for the *Bacilli* is somewhat higher in practice, although comparable figures were also found. The Total Plate Count and the amount of *Staphylococcus aureus* are alike. In general the results from the household washes are strongly in line with the average laboratory results. The results also show that the variations between the different household washes are very small. Statistical analysis did not show any differences between the average laboratory test results and the results of the household washing processes (ANOVA-One Way, $\alpha = 0.05$). The average results of the laboratory test at 60°C are again based on tests from Greece, Norway and the Netherlands. The results of the two processes with bleaching agents (average results of the laboratory test and wash G) are highly comparable. The colony count of the washing process without bleaching agents is, as expected, somewhat higher.

Table 4-7 Hygienic quality of sterile samples after washing at 60°C [logarithmic count of CFU in 4.7 cm2 sample]

	average results laboratory tests	wash F	wash G
	with bleach	without bleach	with bleach
Total Plate Count	2.2	3.0	2.1
Enterobacteriaceae	<0.5	<0.5	<0.5
Bacillus	1.4	2.3	<1.5
St. aureus	<1.5	<1.5	<1.5

Major differences between the laboratory experiment and household daily practice were not found. The amount of Enterobacteriaceae found in the laboratory experiment at 40°C is rather high. In all other cases the colony counts are more or less similar. With the necessary caution it can be concluded that the method seems to be valid and reflects common daily practice.

4.6 Conclusions and considerations

This part of the study assesses the hygiene effects of different laundry processes in four European countries, in particular washing processes at low temperatures (i.e. 15°C and 30°C) in the Wascator and the two most common washing processes in each country of interest. Therefore, the microbiological count of relevant micro-organisms on naturally soiled domestic laundry is determined before and after washing. The results showed that the hygienic quality of the washing processes at low temperatures (i.e. 15°C and 30°C) in the Wascator is rather low. A small reduction in the Total Plate Count was achieved in only some of the cases. For example, the reduction of the Total Plate Count on a diaper sample is about 2.5 to 3 log units. On an unwashed diaper sample, about log 6.5/cm^2 micro-organisms were found. Approximately log 3.8 micro-organisms per cm^2 remain after washing. The hygienic quality of the most common washing processes in Greece, Norway and the Netherlands is more or less comparable. The reduction on the diaper sample varied between 3 and 5.5 log units. About log 1.9 to 4.4 micro-organisms per cm^2 remained after washing. The results from the Spanish washing processes seem to be very different from the other European countries. Only log 0.6 and log 2 micro-organisms per cm^2 remained on a washed diaper. This indicates a higher reduction level. The tests showed that the hygienic quality depends on the washing temperature and the presence of bleaching agents in the detergent as well as on the interaction between these factors. This is confirmed by an additional test. Almost all micro-organisms were removed from the laundry samples in a 95°C programme using a detergent containing bleach.

An interesting question is how these results compare to the hygienic quality of every day clean laundry. The hygienic quality is evaluated directly after washing while the samples are still wet. On clean, dry laundry the Total Plate Count is considerably lower. Samples taken from clean laundry in a cupboard show that the average count is about log 2.5 CFU /4.7cm^2. Drying and ironing seem to have a positive effect on the amount of micro-organisms. One of the most interesting findings is that washing seems to spread micro-organisms rather than removing them. Sterile samples were very often contaminated with all kinds of bacteria. But the sterile samples are not the only indication of cross-contamination and the spreading of micro-organisms. Spreading is also found among laundry items. For example, Enterobacteriaceae were found only on the unwashed diaper and dishcloth, but all other items were contaminated after washing.

Another interesting outcome of this research is the increase in hygienic quality of the laundry items achieved by adding an extra rinse to the washing process. This finding emerged when verifying the Spanish results. The Spanish hygiene level seems to be systematically higher than in the other European countries. One explanation for this could be the extra rinse, which was added to the wash cycle due to extensive foaming. In an additional experiment the effect of an extra rinse was tested. The hygienic quality was improved by more than 1 log unit.

4.6.1 Evaluation of the test method

The repeatability and validation of the method developed were evaluated in Chapter 4.6.1 and 4.6.2 The results showed that the method seems to be repeatable, is valid and reflects common daily practice. However, before bringing this method to the attention of standardisation bodies, research institutes, industry and others, some considerations have to be made. Further research is required to fine tune the test method itself as well as the sampling method and the choice of samples in particular.

Sampling

The paper shredder is able to cut the samples into small pieces but it is not a practical apparatus. The sharp side has many small parts - which are difficult to disinfect. The risk of contaminating the samples while cutting them is real. When the research objective is to get an indication of the presence of micro-organisms, this contamination risk may be acceptable (within limits). When the object is to determine the amount of micro-organisms, the paper shredder is not the best option. The shredder cannot be used to cut items like a sock because of the shape. The pieces would not have the same length. That is why this sample was cut into pieces by hand.

The selection of samples

Four different laundry items were chosen for this experiment: a diaper, a dish-cloth, a handkerchief and a sock. The diaper and the dishcloth proved to be good samples. They are flat and rectangular pieces of laundry which are easy to cut. The expected bacteria were present in abundant amounts. The handkerchief is also flat but slightly fragile. Cutting is difficult because the material is a thin layer. The *Staphylococcus aureus* that were expected were actually found. The micro-organisms that were expected, the yeasts and fungi, were not found in the socks that were used in these tests. Various micro-organisms were present and some of them disturbed the enumeration of *Staphylococcus aureus*. This item could be left out of further experiments because it proved to be an ineffective sample.

Is natural contamination a good way to see a hygiene effect?

The main problem with natural contamination is that the nature and degree of contamination is difficult to control. During this study the amount of micro-organisms that were found prior to conducting the tests was more or less the same. This means higher levels in the diaper and dishcloth samples and fewer micro-organisms in the sock and handkerchief samples[19].

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[19] Health regulations state that a reduction of at least log 5 or log 6 is needed for good disinfection. To find reductions of this magnitude, the unwashed samples should have a colony count of at least log 6. Only the diaper and dishcloth samples in this study (using naturally soiled laundry) meet these criteria for evaluating the Total Plate Count and the Enterobacteriaceae. In all other cases the colony count is so low that an artificial contamination would be needed to investigate the level of disinfection.

The selection of micro-organisms
Enterobacteriaceae are easily removed from the laundry items, but there are still some bacteria left after washing. They are spread throughout the washing machine and the laundry items. Washing at 60°C reduces the amount of Enterobacteriaceae almost to zero.In general, washing reduces the amounts of *Bacilli* considerably. There is nevertheless one exception. In one sample *Bacillus cereus* was found. *Bacillus cereus* proved to be a bacteria which survives the washing process at 40°C and even at 60°C. It is to be expected that it would also survive at lower temperatures. Only washing at 60°C with bleach will remove *Staphylococcus aureus* from the laundry items. This is exactly what Walter et al.[6] discovered. Fewer *Staphylococcus aureus* are removed when washing at 15°C than when washing at 30°C or 40°C.The *Total Plate Count* showed that even after washing with bleach at 60°C, bacteria are left in the laundry. The Total Plate Count gives a good impression of the overall hygiene quality. Throughout the tests, no high numbers of yeasts and fungi were found. With the small numbers in these tests it seems that even a 60°C wash with bleach does not remove all yeasts. Fungi are removed more easily. Fungi were found only after a wash at 15°C. It appears that bleach has some extra effect.

5 Environmental protection, consumer interests and safety and guidelines for standardisation bodies

5.1 Environmental protection

In the domestic textile washing processes there are several factors that could be looked upon as determinants of impact on the environment. These factors can be divided into three groups:

1. Water (amount of water used)
2. Temperature (energy use)
3. Detergents (pollution).

Because of these environmental effects, efforts to achieve a sustainable lifestyle have influenced household laundering significantly during the past three decades. Hereafter it will be shown that the measures that have been introduced to protect the environment not only affect the environmental impact of laundering but are also likely to influence levels of hygiene in the households and thus the public health situation.

5.1.1 Water

Household water consumption has increased in recent decades. In the Netherlands, for instance, about 25 % of household water consumption is for textile cleaning and dishwashing [23]. On the output side of the household system, the drained wastewater burdens water clearing plants and/or the surface waters. Modern-day domestic appliances use less water than those of a few decades ago. However, this must be seen in relation to an important function in the laundry process, namely rinse performance.

Low water consumption during the rinse process results in lower rinse performance (Sommer) [17]. In washing machines the water levels in the wash and rinse phases have been lowered and where applicable one or two rinse cycles have been eliminated. Both measures may lower the rinsing efficiency and thus leave more soil, including micro-organisms, in the washed laundry. To compensate for this, the rinse programmes have been modified. It is questionable whether this can provide enough compensation.

The overall results from the hygiene tests of the Spanish detergents cast an interesting light on the effect of using more water compared to raising the water temperature. Since the investigations and the development of the test method show that the bacteria tend to spread rather than disappear, this could be a possible explanation as to why an extra rinse affects the hygiene results favourly. In a consumer perspective, the effect of extra rinses is also interesting in the light of allergic reactions.

5.1.2 Temperature

A very general finding in this research is that in daily laundering, the cleaning properties expressed as washing efficiency are worse at lower temperatures. Lower temperatures mean lower hygiene levels. This is due to reduced germ elimination combined with increased cross-contamination.

According to Dutch research, textile laundering and dishwashing are responsible for a significant share (about 20%) of domestic energy consumption [24]. Modern-day domestic appliances are designed to use less energy. But the present situation is not sustainable and further measures are needed. Information systems such as Nordic Swan and “Das Grüne Punkt” on the national level and the E-label and ECO-label on a European level, along with information disseminated by consumer bodies, have influenced consumer practices. Currently European consumers in general wash at lower temperatures, but as the results of the survey in chapter 2 show, at the same time the washing frequency per capita has increased.

When we look at the results of washing efficiency related to temperature dependency, we see that the traditional detergents in Spain and Greece show results dependent on temperature (higher temperature – better performance). In both countries traditional detergents are most commonly used. In Norway the compact detergent is the most temperature sensitive when it comes to performance. For the Netherlands, both the compact and the more traditional type of detergents are temperature dependent.

Consumers may or may not accept a reduction in wash performance, and if washing machines and detergents are not improved enough to counterbalance this effect, we might find that common European laundering practices move towards higher wash temperatures again. From the findings reported in chapter 2, we have seen that consumers wash their clothes quite often. Even though this is not a good alternative for the environment, this could be looked upon as a way of solving the problem of a lower wash performance. It should be mentioned here that the quality of the textiles to be washed and the care labelling of these are of great importance to how consumers deal with their laundry.

The energy label on detergents specifies the cleaning efficacy, and the ECO-label requires a minimum of cleaning power. The latter shows that measures are taken to link water temperature to the cleaning efficiency of detergents.

What is to be preferred, high temperatures or more rinsing? From the results shown in chapter 4, both approaches can improve the level of hygiene. But both have an adverse effect in terms of the environmental impact of laundering. Higher wash temperatures require more energy, which means greater carbon dioxide emissions. But more rinses require more tap water. On the basis of the present insights into the impact of energy consumption and water use, an increase in water consumption would be chosen. Water is not scarce in Europe, and the production of water requires very low amounts of energy and chemicals.

5.1.3 Detergents

The use of detergents is linked to the depletion of resources, since the production of these chemicals requires natural resources, which are non-recoverable raw materials. It is also linked to pollution of the water systems, as the used detergents are drained with the wastewater. National and European legislation, such as the ban on phosphate and non-biodegradable surfactants, has steered industry into a more sustainable direction. In an attempt to reduce the environmental impacts, detergents have been made more effective and have been concentrated, both measures leading to lower detergent consumption. In the Netherlands, for instance, the dosage for a normal washing programme for whites has gone down from ± 170 grams per cycle in 1980 to ± 65 grams in 2000 [25]. This reduction means lower detergent concentrations in the suds, which in turn is likely to reduce their contribution to the degree of chemical disinfection in the washing process. The results from the washing efficiency tests in chapter 3 show that there are great variations in the results among the countries investigated. The traditional Spanish detergent tested has better wash performance than the compact detergent tested. Greece, on the other hand, has a compact detergent where the tests show significantly better results than for the traditional detergent. In Spain the traditional detergent is a best seller and consumers use low temperatures, whereas the Greeks use higher temperatures and detergents are designed to perform best at high temperatures. As the results verify, detergents are more likely to be adjusted to the market than to considerations of sustainability.

At low washing temperatures, bleach systems based on persalts are much less effective for soil removal and disinfection. This adverse effect can be compensated for substantially by the addition of bleach activators, e.g. tetraacetylethylenediamine (TAED). At low washing temperatures the effect of activated bleach systems decreases as well. Detergents for coloured articles meant for washing temperatures of 60°C or less do not contain bleach and will therefore show poor properties of disinfection.

Finally it should be mentioned that the focus on eco-labels, such as the Nordic Swan and the EU-flower, has also contributed to a more sustainable development. The numbers of detergents that are listed as more environmentally friendly has increased in recent years. [26].

5.2 Consumer interests and safety related to hygiene

The boil wash laundering process, which was used traditionally, showed appropriate cleaning properties combined with excellent hygiene efficacy. As mentioned in the previous sections, lower wash temperatures result in lower hygienic quality. Thus it may be assumed that for domestic textile laundering the measures to reduce energy consumption may have stressed the conditions for proper hygiene.

Until recently, however, little attention has been paid to the hygienic properties of daily modern laundering practices. As clothes hygiene is the major benefit of laundering (apart of the removal of visible soil and stains), more insight in the hygienic implications of modern laundering practices is needed for the sake of policy measures on public health and environmental policy issues. In order to reduce household water consumption, different new type of cleaning processes have been adapted. For washing machines this has been expressed as reduction of water levels in the wash and rinse phases, and where applicable also one or two rinse cycles have been eliminated. Both measures may lower the rinsing efficiency and therefore leave more soil, including micro-organisms, in the washed laundry. To compensate for this, the rinse programmes have been modified. It is questionable whether this can provide sufficient compensation.

An important question is what level of hygiene should be maintained in a domestic environment. This is dependent on a number of variables. There is experimental evidence showing a relationship between domestic hygiene and health. It is only very limited, however, and has only been established for the American situation. [27]. The risks are greater if vulnerable people, i.e. children, the elderly and people with compromised immune systems, are exposed to insufficient laundry hygiene. But even then it should be realised that there is no quantitative information about the relationship between laundry hygiene and public health.

In the field of domestic hygiene, the present view is that practices promoting higher hygiene levels should be targeted. For the application of this targeted hygiene, it is required that the risk situations are known and specified and that the efficacy of individual domestic processes is known in detail. It is very important in further discussions that the level of hygiene not is raised at the cost of environmental impact or at levels that have no benefits for public health. Infections versus hygiene should also take into consideration the risk aspect. There is a current tendency to do most anything in the name of "hygiene". Neutral facts are essential in order to allow for a balanced discussion on this topic.

Another important factor is the great increase in the types of textiles available. These textiles are mostly labelled for wash at low temperatures (30° and 40°C), and the new textiles have resulted in new ways of doing laundry, as well as new detergents that are specially made for modern textiles. For the consumer, the quest for clean and odourless textiles and the fact that clothes should be washed at low temperatures might raise some problems. In most cases laundry is performed to get textiles clean. Clothes with dirt and stains or residuals of detergents may constitute both aesthetic and health problems. Dirt can spread infectious disease, and residuals of soap in clothes can cause allergic reactions. In addition, a washing result that is not satisfactory can result in negative environmental effects, because of more frequent laundering and ruined clothes. Finally, a washing result may not be satisfactory is a social context. Using stronger detergents can be considered a solution to these problems.

Several institutions monitor the cleaning properties of changing laundering practices. Consumer bodies assess and publish the efficacy of cleaning products such as textile detergents on a more or less regular basis. These publications are popular reading and show that given the right circumstances, consumers want information regarding laundry.

Investigations show that in spite of modern machines and the many appliances that have been developed just to save time for the person in charge of the domestic laundry, and in spite of the availability of more effective detergents, more time may be spent on “washing processes” today than previously. One explanation for this could be that more and more clothes are designed that need special care – and some are even impossible to wash. Even though there are no empirical data to verify this, it seems as though there is little awareness of the inadequacies of washing instructions and that other aspects of the garments are of greater interest to the consumer. Combined with an extensive use of “under-labelling” (i.e. the label indicates that the textile is to be washed at 30°C, when it could be laundered at 40°C or 60°C), this results in more time being spent doing laundry. It should be taken into consideration in this context that it is difficult for the consumer to become oriented when faced with different recommendations. If something goes wrong during the washing process, having used other temperatures than those indicated on the wash label could entail great difficulties when it comes to claims. The solution chosen is often to wash at a lower temperature when in doubt.

Washing practices in the real life situation differ from laboratory conditions as well as from household to household and country to country. Therefore it should be emphasized that the previous laboratory research and theoretical assumptions cannot give a reliable insight into the total hygienic level of laundering in the real life situation nor of the national variation within Europe.

Summarising, the measures that have been introduced to reduce the environmental impact of household laundering are likely to have an adverse effect on the conditions for appropriate hygiene.

5.3 Guidelines for standardisation bodies

An important function during the laundry process is the rinse performance. Since this is related to both the allergenic effects and the hygienic quality, an initiative is needed to investigate this issue in the standardisation bodies. Many methods have been used to determine rinse performance (or rinse efficiency as it is also called), but unfortunately none have been proved reproducible. Thus there are no available data defining an acceptable level for rinse performance, but when tap water is used as a reference we might have a guideline. SIFO (the National Institute for Consumer Research) is represented in the working group appointed by the Nordic Council of Ministers to find a reproducible method for the determination of rinse efficiency, but this work has not yet been completed. For the time being the method described in the international standard IEC 60456 will be used. This is especially important for the committees dealing with washing machines: IEC TC 59 D and Cenelec 59D and their subcommittees and maintenance teams.

The relationship between standardisation of household washing machines, household textile detergents and labelling of textiles deserves scrutiny in light of the findings in this project. It is obvious that there are connections here that should be given more attention when writing standards. The principle of taking into account the possibility for a consumer to make mistakes is important in other parts of standardisation ("foreseeable misuse"). This principle should also be vitalised in the issues of washing textiles. The dosage of detergents related to the hardness of water is another factor that should be given more attention. The relationship between the dosage given (per kilogram textiles) and how easy is it to determine this when starting a household washing machine is also interesting.

The standardisation of environmental impacts is a complex issue. However, this should not prevent the use of continued efforts to find best possible practices, in order to make consumers aware of the implications of their behaviours.

Energy labels must continue to contain information on washing results as part of the information to the consumer. For the Nordic Swan and the EU-flower, it is essential that the criteria documents continue to be revised in order to take into account new developments.

Labelling of textiles in a global perspective is needed because garments today are produced worldwide. Focus must therefore be kept on the issue of care labelling. ISO/TC 38 is one committee dealing with this issue, and efforts should be redoubled, if possible, to achieve even greater efficiency when it comes to the standardisation of care labels.

6 Further recommendations

It has become clear from this research that laundering practices, consumer attitudes and the efficacy of laundering processes differ substantially between the European countries.

This is one of the reasons why the primary effect of laundering – the removal of soil – differs from one country to another. But these factors also impact the level of hygiene.

A very general finding is that in daily laundering, the cleaning properties are poorer at lower temperatures. Thus lower temperatures mean lower hygiene levels. Further research into this matter is needed, and policy measures should be developed to inform consumers about this matter.

Proposals for further investigations:

- In the present research, the effect of the washing machine type has not been taken into account. As such influence is likely, initiating research on this aspect is recommended.

- The results of this research for the Spanish situation show that even at low wash temperatures an appropriate level of cleaning and hygiene can be achieved. It could prove rewarding to further investigate the Spanish situation.

- Further studies to investigate the types of textiles and the impact of detergents and the washing programme cycles on them should be considered. This is particularly of interest in light of the rapid development of clothes and garments using many new combinations of textiles.

- Further analysis of the composition of detergents on a neutral basis in order to investigate hygiene and impact on textiles would be most interesting.

- Research into optimisation of the laundering process with respect to hygiene is urgently needed.

- There are important interrelations between washing frequency, textile type, wash temperature and detergent; the present research did not include the influence of textile type. This should be investigated in future research.

- It is worthwhile to investigate the hygienic quality of the laundry when it has dried with different, sustainable and non-sustainable, drying methods.

- Until recently, little attention has been paid to the public health function of laundering. The introduction of an information campaign for consumers on this topic should be considered.

- It may be worthwhile to work for including hygiene performance on the energy label and the ECO label of detergents.

- The impact of softeners on the washing process and on the hygiene issue would be most interesting to investigate further.

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Appendix A
Survey of domestic laundry habits in europe, the questionnaire

1. Good afternoon. My name is……..and I am calling from ….regarding an investigation of domestic laundry habits. I would like to speak with the person who has the main responsibility for handling the laundry in your household. (If two or more persons share this responsibility, ask for the person with the last birthday)

(When the correct person is at the phone): Good afternoon. My name is ….. and I am calling from ….. regarding an investigation of laundry habits. Could you spare five minutes to answer some simple questions?

1.How many hours does your household spend on laundry during a regular week?___________Hours

2.Does your household dispose of (READ OUT):

		Yes	*No*	*Don't know*
1.	A private washing machine	1	0	8
2.	A private tumble drier	1	0	8

IF THE HOUSEHOLD DOES NOT DISPOSE OF A PRIVATE ELECTRIC WASHING MACHINE (Question 2.1=NO):

3.How does your household usually handle laundry? (Only one answer)

1.	***Washing machine owned by several households***	**1**
2.	Coin laundry	2
3.	The cleaners/Dyers	3
4.	By hand washing	4
5.	Other ways	5
8.	Don't know	8

ALL RESPONDENTS:

4.How often does your household change bedsheets? Is it: (READ OUT)

1. Several times a week	1
2. Once a week	2
3. Every second week	3
4. Every three weeks	4
5. Monthly or less frequent	5
9. Don't know (DO NOT READ)	8

5. How many times do you wear/use the following garments before they are washed or sent to the cleaners?

1. Jeans	Number of times_____	98 Don't know 99 not relevant
2. Thin woollen sweater	Number of times_____	98 Don't know 99 not relevant
3. Blouse/shirt of synthetic material	Number of times____	98 Don't know 99 not relevant
4. Cotton T-shirt	Number of times_____	98 Don't know 99 not relevant
5 Bath towels	Number of times_____	98 don't know 99 not relevant
6 Thin socks	Number of times_____	98 Don't know 99 not relevant
7 Underpants	Number of times_____	98 Don't know 99 not relevant

6. Do you have a spouse or a partner?

1.Yes	1
2.No	0 → Go to question 8

7. How many times does your spouse or partner wear/use the following garments before they are washed or sent to the cleaners?

1. Jeans	Number of times________	98 Don't know 99 not relevant
2. Thin woollen sweater	Number of times________	98 Don't know 99 not relevant
3. Blouse/shirt of synthetic material	Number of times________	98 Don't know 99 not relevant
4. Cotton T-shirt	Number of times________	98 Don't know 99 not relevant
5. Bath towels	Number of times________	98 Don't know 99 not relevant
6. Thin socks	Number of times________	98 don't know 99 not relevant
7. Underpants	Number of times________	98 Don't know 99 not relevant

8. I will now read to you a number of textile types. In what way are these textiles usually washed by the household: Is it by hand, in a washing machine, at the cleaners or in other ways? (READ TEXTILE TYPES)

	By hand	Machine	Cleaners	Other	Don't know	Not relevant
1. Bedsheets	1	2	3	4	8	9
2. Jeans grown up person	1	2	3	4	8	9
3. Thin woollen sweater	1	2	3	4	8	9
4. Blouse/shirt of synthetic material	1	2	3	4	8	9
5. Cotton T-shirt (grown up)	1	2	3	4	8	9
6. Bath towels	1	2	3	4	8	9
7. Thin socks	1	2	3	4	8	9
8. Underpants	1	2	3	4	8	9

9. Which temperature (degrees Celsius) do you usually apply when washing the following clothes and garments (READ GARMENTS TYPES):

	Cold water	30°	40°	60°	70°	90°	Don't know	Not relevant
1. Bedsheets	1	2	3	4	5	6	8	9
2. Jeans grown up person	1	2	3	4	5	6	8	9
3. Thin woollen sweater	1	2	3	4	5	6	8	9
4. Blouse/shirt of synthetic material	1	2	3	4	5	6	8	9
5. Cotton T-shirt (grown up)	1	2	3	4	5	6	8	9
6. Bath towels	1	2	3	4	5	6	8	9
7. Thin socks	1	2	3	4	4	6	8	9
8. Underpants	1	2	3	4	5	6	8	9

10. How many different <u>types</u> of textile detergents does your household dispose of?
Number of
detergents_____________________ Don't know 88 If no detergents (0), → Go to question 12.

11. I will now read to you some remedies that can be applied for washing of clothes. For each remedy, I will ask you whether it is always used, often used, used occasionally or never by your household? (READ REMEDIES)

	Never	Occasionally	Often	Always	Don't know
Washing Powder	1	2	3	4	8
Washing Tablets	1	2	3	4	8
Washing Liquids	1	2	3	4	8
Detergents for delicate clothes	1	2	3	4	8
Detergents for coloured clothes	1	2	3	4	8
Chlorine treatment or other bleaching agents	1	2	3	4	8
Stain remover	1	2	3	4	8
Measuring cup for the dosage of detergent	1	2	3	4	8
Fabric conditioner	1	2	3	4	8

12. I will now read to you some statements regarding laundry habits, and would like to know whether you agree or disagree. We adopt an answering scale ranging from 1 to 5, where 1 signifies "fully disagree" and 5 signifies "fully agree". (READ STATEMENTS)

	Fully disagree	Partly disagree	Neiher agree nor disagree	Partly agree	Fully agree	Don't know
1.Clothes should always smell as if newly washed	1	2	3	4	5	8
2 People today generally wash their clothes too often	1	2	3	4	5	8
3.It is important to me that my clothes are hygienic clean	1	2	3	4	5	8
4.Today's detergents are so good that clothes get clean even when washed at low temperatures	1	2	3	4	5	8
5.Modern washing habits are generally harmful to the environment	1	2	3	4	5	8
6. It is embarrassing to wear clothes with a body odour	1	2	3	4	5	8
7. I always examine washing instruction tags carefully	1	2	3	4	5	8
8. Boiling is unnecessary when washing white clothes because modern detergents make them stay white anyway	1	2	3	4	5	8
9. Laundry wears clothes out more so than actually wearing them	1	2	3	4	5	8
10. Hot water wears out clothes more than cold water	1	2	3	4	5	8

13. Record gender.

1.Male 1
2.Female 0

14. What is your age?

— —

15. What is your civil status. Are you…(READ OUT)

1.Married	1
2.Co-habitant	2
3.Previously married/widow(er)	3
4.Never married	4
5.No answer (DO NOT READ)	5

16. How many persons live with your household, including yourself?

— —

17. Which of the following occupational descriptions suits your current situation the best. Are you.. (READ OUT)

1.Working, in private sector	1
2.Working in public/government sector	2
3.Working, as self-employed	3
4.Pensioner	4
5.Pupil/student	5
6.Unemployed	6
7.Full-time housewife	7
8.No answer (DO NOT READ)	8

18. What is your highest completed educational level?

1.Basic	1
2.Intermediate	2
3.Secondary (high-school)	3
4.University	4

19. What is the approximate size of the total gross (before taxes) household income?
__ __ __ __ __ (Local currency)

20. Region
__ __ __ __ __ (Regional code)

INTERVIEWER INSTRUCTION

1. Background
This survey is an international investigation of laundry habits, running in parallel in three European countries: Greece, the Netherlands and Norway. Our clients are research institutes who have very precise requirements regarding quality standards. Also the fact that the surveys should be comparable across countries, requires a high degree of accuracy during the interview conduct in order to assure that questions are posed in exactly the same way across countries. Samples are nationally representative household samples, n=1000, in each country. The survey addresses the person who is the main responsible for household laundry.

2. Filtering:
The questionnaire adopts 3 filters:
1. A filter is inserted in question 2, where only households who do not dispose of a private washing machine, will answer question 3, while households that do dispose of a private machine skip to question 4.

2. In question 6, a filter is introduced where respondents who have a spouse or partner will answer question 7, while respondents who do not have a spouse or partner skip to question 8.

3. In question 9 the filter directs households who do not have any textile detergents in the household to question 11, while households who do have such remedies are asked to specify them in question 10.

3. Explanations and definitions
The following questions may involve interpretation differences, and are hence defined as follows:

Question 2:
This question refers to machines at the private disposal of the household. That is, they are used exclusively by the household itself
Definitions:.
- A “washing machine” is an electrical machine for washing of textiles.
- A “tumble drier” is an electrical machine for drying of textiles.

Question 3:
This question is addressed to household who do not dispose of a private washing machine, and lists alternative ways of handling laundry..
Definitions:
- A “washing machine owned by several households” is a machine that is shared by several households, for example a housing co-operative.
- A “coin laundry” is a place where you rent a washing machine.
- A “cleaner” is a place where professionals wash or dry your clothes.

Question 5 & 7:
These questions measure the number of times a person is wearing various garments before they are washed. Because a person can wear several outfits during one day (for instance for work and leisure time), we want to use the term “times” rather than for example “days”.

Question 9:
This question identifies washing temperatures used when washing laundry. Temperature is registered in degrees Celcius. - If the respondent has a problem in generalising this question he/she may answer with regard to his/her own clothes
- If the respondent answers “lukewarm water” this should be coded as 30° C.

Question 10:
This question refers to different <u>types</u> of detergents at the disposal of the household – not the number of (same) detergents.
Definitions:
- By “textile detergents” we mean powder, liquid or tablets that are added to the washing water to make the clothes clean

Question 11:
This question identifies washing remedies used by the household.
Definitions:
- “Chlorine treatment is the same as “bleaching remedies for white clothes”
- “Stain remover” is a special remedy used for removing of stains that are particularly hard

Appendix B
Declaration detergents

Greece

A)

B) Skip (traditional powder)
UNILEVER HELLAS AEBE, Μαρίνου Αντύπα 92, T.K 141 21, N.Ηρακλειο.
Αρ.Καταχ. 380/8/2002
Ingredients:
15-30 % Phosphates
5-15 % Anionic surfactants, Nonionic surfactants, Oxygen based bleaching agents
<5 % Soap, Phosphonate, Polycarboxylates
Enzymes

C) Ariel Essential Alpine (liquid)
PROCTOR & GAMBLE, P.O.Box 268, 1213 Petit-Lancy 1, Geneva, Switzerland.
Ingredients:
15-30 % Anionic surfactants
5-15 % Soap, Nonionic surfactants
<5 % Phosphonates, Cationic surfactants
Enzymes (Cellulase, Glycosidase, Protease), Optical brightener

D) Skip Tablets
UNILEVER HELLAS AEBE, Μαρίνου Αντύπα 92, Τ.Κ 141 21, Ν.Ηρακλειο. Αρ.Καταχ. 4193/3/2001
Ingredients:

>30 %	Phosphates
15-30 %	Zeolites
5-15 %	Anionic surfactants, Oxygen based bleaching agents
<5 %	Soap, Nonionic surfactants

Enzymes

The Netherlands

A) Ariel Tablets
PROCTOR & GAMBLE, P.O.Box 268, 1213 Petit-Lancy 1, Geneva, Switzerland.
Ingredients:

5-15 %	Anionic surfactants, Zeolites, Oxygen based bleaching agents
<5 %	Soap, Phosphonate, Nonionic and cationic surfactants, Polycarboxylates

Enzymes (Amylase, Protease), Brightening agent (optical brightener).

B) Omo (concentrated powder)
LEVER FABERGÉ, Antwoordnummer 10678, 2410 VB Bodegraven.
Ingredients:

>30 %	Zeolites
15-30 %	Oxygen based bleaching agents
5-15 %	Anionic and nonionic surfactants
<5 %	Soap, Phosphonate, Polycarboxylates, Enzymes (Protease, Cellulase, Lipase), Optical brightener, TAED (bleach activator)

C) Robyn Intensif (liquid)

D) Ariel Color Tablets
PROCTOR & GAMBLE, P.O.Box 268, 1213 Petit-Lancy 1, Geneva, Switzerland.
Ingredients:

5-15 %	Anionic surfactants, Zeolites
<5 %	Soap, Phosphonate, Nonionic and cationic surfactants, Polycarboxylates

Enzymes (Amylase, Cellulase, Protease)

Norway

A) Omo Ultra Tablets
LILLEBORG AS, P.O.Box 4236 Nydalen, 0401 Oslo.
Ingredients:

15-30 %	Zeolites
5-15 %	Anionic surfactants, Oxygen based bleaching agents
<5 %	Soap, Nonionic surfactants, Phosphonate, Enzymes

B) Omo TAED Plus (traditional powder)
LILLEBORG AS, P.O.Box 4236 Nydalen, 0401 Oslo.
Ingredients:

15-30 %	Zeolites
5-15 %	Anionic surfactants, Oxygen based bleaching agents, Non-ionic surfactants
<5 %	Soap, Polycarboxylates, Enzymes, Phosphonate

C) Omo Color Liquid
LILLEBORG AS, P.O.Box 4236 Nydalen, 0401 Oslo.
Ingredients:

15-30 %	Nonionic surfactants
5-15 %	Soap, Anionic surfactants
<5 %	Polycarboxylates, Enzymes

D) Omo Color Tablets
LILLEBORG AS, P.O.Box 4236 Nydalen, 0401 Oslo.
Ingredients:

15-30 %	Zeolites
5-15 %	Anionic surfactants
<5 %	Soap, Nonionic surfactants, Phosphonate, Enzymes

Spain

A) Puntomatic (tablets)
PERSAN S.A., Ctra. de Málaga, Km 1,5. 41016 Sevilla.
Ingredients:

15-30 %	Phosphates
5-15 %	Anionic surfactants, Oxygen based bleaching agents
<5 %	Nonionic surfactants, Polycarboxylates

Enzymes

B) Ariel Alpine (traditional powder)
PROCTOR & GAMBLE, P.O.Box 268, 1213 Petit-Lancy 1, Geneva, Switzerland.
Ingredients:

15-30 %	Zeolites
5-15 %	Anionic surfactants, Oxygen based bleaching agents
<5 %	Soap, Nonionic and cationic surfactants, Polycarboxylates

Enzymes

C) Micolor Gel (liquid)
HENKEL IBÉRICA, S.A.., Córega, 480 – 08025 Barcelona.
Ingredients:

5-15 %	Nonionic surfactants
<5 %	Soap

D) Puntomatic Color Cor (tablets)
PERSAN S.A., Ctra. de Málaga, Km 1,5. 41016 Sevilla.
Ingredients:

>30 %	Phosphates
15-30 %	Anionic surfactants
<5 %	Nonionic surfactants, Polycarboxylates

Enzymes

Appendix C
Settings of the 15°C Wascator washing programme for the hygiene tests

All settings not listed below are set to “no”.

Main wash 01
Gentle action during filling: yes
Gentle action during heating: yes
Gentle action during wash: yes
Level: 076 units
Hystereses: 020 units
Temperature: 015°C
Wash time: 30 min.
Cold water: yes
Comp. 2 (level controlled): yes
Drain 01
Gentle action: yes
Time: 01 min.
Extract 01
Spinning time: 01 min.
Rinse 01
Gentle action during filling: yes
Gentle action during heating: yes
Gentle action during wash: yes
Level: 076 units
Hystereses: 020 units
Temperature: 015°C

Wash time: 05 min.
Cold water: yes

Drain 02

Gentle action: yes
Time: 01 min.

Extract 02

Spinning time: 01 min.

Rinse 02

Gentle action during filling: yes
Gentle action during heating: yes
Gentle action during wash: yes
Level: 076 units
Hystereses: 020 units
Temperature: 015°C
Wash time: 05 min.
Cold water: yes

Drain 03

Gentle action: yes
Time: 01 min.

Extract 03

Spinning time: 01 min.

Rinse 03

Gentle action during filling: yes
Gentle action during heating: yes
Gentle action during wash: yes
Level: 076 units
Hystereses: 020 units
Temperature: 015°C
Wash time: 05 min.
Cold water: yes

Drain 04

Gentle action: yes
Time: 01 min.

Extract 04

Spinning time: 06 min.

Appendix D
Settings of the 30°C Wascator washing programme

All settings not listed below are set to “no”.

Main wash 01
Gentle action during filling: yes
Gentle action during heating: yes
Gentle action during wash: yes
Level: 076 units
Hystereses: 020 units
Temperature: 030°C
Wash time: 30 min.
Cold water: yes
Comp.2 (level controlled): yes
Drain 01
Gentle action: yes
Time: 01 min.
Extract 01
Spinning time: 01 min.
Rinse 01
Gentle action during filling: yes
Gentle action during heating: yes
Gentle action during wash: yes
Level: 076 units
Hystereses: 020 units
Temperature: 015°C

Wash time: 05 min.
Cold water: yes
Drain 02
Gentle action: yes
Time: 01 min.
Extract 02
Spinning time: 01 min.
Rinse 02
Gentle action during filling: yes
Gentle action during heating: yes
Gentle action during wash: yes
Level: 076 units
Hystereses: 020 units
Temperature: 015°C
Wash time: 05 min.
Cold water: yes
Drain 03
Gentle action: yes
Time: 01 min.
Extract 03
Spinning time: 01 min.
Rinse 03
Gentle action during filling: yes
Gentle action during heating: yes
Gentle action during wash: yes
Level: 076 units
Hystereses: 020 units
Temperature: 015°C
Wash time: 05 min.
Cold water: yes
Drain 04
Gentle action: yes
Time: 01 min.
Extract 04
Spinning time: 06 min.