

WISSENSCHAFTLICHER BEITRAG

Washing-up Behaviour and Techniques in Europe

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With this study we open the kitchen area to disclose how the washing-up is done in European households. Surprisingly for all, the habits and practises seen vary dramatically between individuals, but less so between gender or between different countries of origin. Protocols of washing-up are therefore given as case reports showing the variety of habits and practises used. Recorded consumption of energy, water and cleanser show huge differences as well with almost no correlation to achieved cleaning performance. Especially when comparing with an automatic dishwashing machine, average manual dishwashing turns out to consume significant more resources.

1 Introduction

Dish washing has been studied before (Luecke 1971), reporting on four housewives competing with an automatic dishwasher, or (Gudd et al. 1994) when ten persons wash a larger amount of dishes and the results were compared with those produced by dishwashing machines. Systematic comparisons (Gutzschebauch et al. 1996) include environmental, economic and social factors on both ways of making up the dishes. At the time they were conducted and based on data for Germany (Gudd et al. 1994), they showed little difference regarding the total energy input and total costs. This situation is different today (Stamminger 2006) as products and costs have changed considerably. Consumer organizations have also taken up this issue, reporting occasionally on comparisons between manual and automatic dishwashing (Stiftung Warentest 1995).

So far, national or regional differences in washing-up practises have not been reported. First hints about differing washing-up practises can be found in sociological works. Studying influencing factors on energy consumption in private households in Japan and Norway (Wilhite et al. 1995) highlight the cultural influence on differences in consumer behaviour.

Therefore the target of this study was to investigate consumer habits and dish washing techniques throughout Europe by quantitative and qualitative methods. Special emphasis was placed on the attempt to find out which kind of technique used delivers what level of cleaning performance at which amount of resources and time needed. An additional aim was to perform a comparison between manual and automatic dishwashing on as broad a statistical and geographical basis as never before. A minimum of 10 people per region was seen appropriate to see differences in habits and practises of manual dish washing.

While previous publication (Stamminger et al., 2003) was based on a limited number of participants, this report gives the complete picture on the numerical data gathered, but also analyses the behavioural side of the cleaning process as observed.

2 Material and methods

To acquire data for comparing the habits of consumers from different countries, one prerequisite was to perform the tests under conditions that were as uniform as possible. Accordingly the tests were performed mainly in one laboratory (at the University of Bonn), where visitors of Bonn from seven countries/regions were asked to wash an assortment of dishes. To make sure that they had not adopted 'German behaviour', care was taken to work with consumers who had not been resident in Bonn or Germany for more than two years. No additional requirement was used in the selection of our

Abspülen in Europa – Techniken und Praktiken

Das Abspülen des Geschirrs wird meist als Teil der täglichen Hausarbeit durchgeführt, ohne viel darüber nachzudenken. Auch haben vielfältige Diskussionen gezeigt, dass diese Arbeit von jedem Einzelnen kaum kritisch reflektiert wird. Für viele überraschend hat diese Tätigkeit sich bei unserer europaweiten Studie mit 113 Probanden aus sieben Ländern/Regionen als äußerst variantenreich herausgestellt. Diese Variationen lassen sich aber nicht am Geschlecht oder Alter festmachen und auch die geographische Herkunft bietet keine eindeutige Zuordnungsmöglichkeit.

Ein Ziel dieser Arbeit ist es deshalb, die Verschiedenheit der verwendeten Abspültechniken aufzuzeigen. Dazu werden unter anderem Protokolle des Abspülverhaltens einzelner Probanden wiedergegeben und das Abspülverhalten soweit wie möglich statistisch beschrieben. Die Verschiedenheit zeigt sich auch in den eingesetzten Mengen an allen verwendeten Ressourcen: Energie, Wasser, Spülmittel und Arbeitszeit. All diese messbaren Größen variieren sehr stark. Letztendlich zeigt ein Vergleich mit der automatisierten Art des Geschirrspülens, dass einzelne unserer Probanden durchaus in einzelnen Parametern ‚mithalten‘ können, insgesamt aber die Geschirrspülmaschine die besseren Leistungen bei geringeren Verbräuchen liefert.

WISSENSCHAFTLICHER BEITRAG

Table 1: Evaluation of cleaning tests

Score	Soil residue	
5	None	
4	Number of small dot-shaped soil particles and total soil area	1 to 4 $\leq 4 \text{ mm}^2$
3	Number of small dot-shaped soil particles and total soil area	5 to 10 $\leq 4 \text{ mm}^2$
2	Number of small dot-shaped soil particles or total soil area	> 10 $> 4 \text{ mm}^2$ to $\leq 50 \text{ mm}^2$
1	Total soil area	$> 50 \text{ mm}^2$ to $\leq 200 \text{ mm}^2$
0	Total soil area	$> 200 \text{ mm}^2$

Source: EN 50242:1998

(The size of 200 mm² is about the size of a 1 Euro-Cent coin.)

volunteers. To verify the assumption that this would lead to a correct picture of consumer behaviour for a specific region, the tests were also done with the same equipment on excursions to laboratories in France, Italy, Spain and the UK.

The test set-up is based on a widely accepted measurement standard (EN 50242:1998) defining methods for measuring the performance, the energy and the water consumption of electric dishwashers, simulating a normal use of tableware and food. This standard was selected, as also previous measurements (Gudd et al. 1994) followed a (previous) version of this standard. Additionally it eases the comparison of manual wash with an automatic dishwasher, as it specifies the load items in a clear way.

According to EN 50242, twelve place settings of dishes (each consisting of a soup plate, dinner plate, dessert dish, cup saucer, glass, fork, soup spoon, knife, teaspoon, dessert spoon and additional serving pieces, in total 140 individual items of crockery, glasses and cutlery) were 'soiled' with seven different kinds of food, namely spinach, minced meat, oat flakes, milk, margarine, tea and egg yolk. But in contrast to the procedures described in EN 50242, these soils were not dried in an oven at 80 °C but exposed to room temperature for two hours lest a systematic disadvantage for manual dish washing be introduced into the test set-up. In normal households, food soils will not be burned in in the same measure as is required for testing and differentiating electric dishwashers. For the same reason, the milk soiling was not burned in as recommended by the standard.

After drying, the 140 items were presented to the test persons in a kitchen-like test room. Two sinks with hot and cold water taps, a variety of cleaning tools, and 22 kinds of washing-up liquid from all relevant countries were made available for the test persons' choice. Asked to clean and dry the dishes 'like he/she would at home', they were then left alone. A video camera and water and temperature sensors produced comprehensive records of each test person's behaviour. After each test, the cleaning performance was assessed visually in accordance with EN 50242, i. e. using an ordinal

scale ranging from 0 to 5 (Table 1), with 0 meaning there are items with an area of residues of $> 200 \text{ mm}^2$ and 5 meaning there are no residues left at all. Obviously, the average over all items being somewhere between 0 and 5 for any one person, it can be taken as a measure of individual cleaning performance.

As energy figures for manual washing just the energy content of the water used for the process was recorded and corrected to a constant inlet water temperature of 15 °C.

Two electric household dishwashers with A/A/A labelling (in terms of the European energy labelling scheme this indicates the best cleaning and drying performance at minimal energy consumption) were run parallel to the consumer tests, using the program recommended for energy labelling purposes and a program recommended for heavily soiled dishes (intensive program). Energy and water consumption of these machines were not measured, but data as declared by the manufacturer for those programs used are reported.

After the practical tests, all test persons were interviewed about their behaviour and attitude towards manual and automatic dishwashing by means of a structured questionnaire. The recorded washing-up behaviour of each test person was analysed off-line and clustered with regard to various aspects of the washing-up process.

3 Results and discussion

Manual dish washing for this study was performed by 113 people from seven European countries/regions (Table 2).

73 % of the volunteers were female and 77 % were below 40 years of age. No special efforts were taken to ensure a 'representative' sampling of the test persons. 35 % of the test persons used a dishwasher in their household, which is roughly equivalent to the distribution of dishwashing machines in European households.

3.1 Attitude

Our volunteers' answers in the questionnaires provided some information on their attitudes towards dish washing:

One reason given by test persons who did not use a dishwasher at home was that there was not enough room in their kitchen (about one third of the non-owners). Other factors, such as the number of people living in a household or the performance and consumption values of automatic dishwashing, were important for some and unimportant for others (Table 3). The picture is clearer with regard to people owning a dishwasher; they saw automatic dishwashing as a

WISSENSCHAFTLICHER BEITRAG

Table 2: Region of origin of test persons and where tested

Region	# of test persons	hereof tested during excursions
Germany	11	
Great Britain, Ireland	27	20
France	18	10
Spain, Portugal	20	6
Italy	15	6
Turkey	11	–
Poland, Czech Rep.	11	–
Total	113	

Source: Own data

way of saving time, and they preferred automatic dishwashing for performance and ecological reasons (Table 4).

In reference to the question about how often they wash their dishes by hand, 50 % of our volunteers said they do so before or after each meal, while the other 50 % said they washed up twice a day at most. This shows clearly that there are two different attitudes: some people want to have an

empty sink, so they wash up whenever there are items to be washed, and other people pile the used dishes up until there is time to wash up.

According to the answers from the questionnaire, roughly 30 % of our participants do their washing-up only under continuously running tap water. The rest usually washed their dishes in a water bath (sink or bowl), and they gave different reasons for replacing the water (Table 5). Surprisingly, the amount of foam is of minor importance in the decision to replace the water. Almost 30 % of our volunteers said they do not give washed items a final rinse with fresh water. Of those who do (multiple answers possible), about 80 % use a final rinse mainly to remove remaining soil particles, and 50 % do so to remove foam (or chemicals). With regard to the order in which items are washed, answers produced a clear ranking (Table 6), where the first (glasses) and last (pots and pans) types of items to be washed have clearer prominence than the rest. As for washing-up tools, no clear preference became evident; sponges are used mainly, but brushes and towels seem to be widely used as well.

From a list of problems and disadvantages of washing up by hand, our participants agreed mainly to ergonomic and performance-related arguments (Table 7) against manual dish washing.

Table 3: Reasons for not owning a dishwasher *

Reasons for not owning a dishwasher	Range of agreement to statement (multiple answers allowed)		
	Important and very important	Less important or less unimportant or no statement	Unimportant and absolutely unimportant
Too few people in household	45%	28%	27%
Dishwasher is too expensive	45%	30%	26%
Hard soils can only be removed by manual washing	32%	42%	26%
Manual washing is more economical in water and energy consumption	24%	46%	30%

Source: Own data

* 74 people not owning a dishwasher

Table 4: Reasons for owning a dishwasher *

Reasons for owning an automatic dishwasher	Range of agreement to statement (multiple answers allowed)		
	Important and very important	Less important or less unimportant or no statement	Unimportant and absolutely unimportant
Many people in household	46 %	33 %	21 %
Dishwashers save valuable time	74 %	23 %	3 %
Dishwashers produce better and more hygienic results	33 %	41 %	26 %
Automatic dishwashing saves water and energy	41 %	46 %	13 %

Source: Own data

* 39 people owning a dishwasher

WISSENSCHAFTLICHER BEITRAG

Table 5: Reasons given for replacing water*

Reasons for changing water	Answers in % (multiple answers allowed)
Water is too turbid / dirty	80
Water has cooled down too far	35
Not enough foam	15
Other reasons	3

Source: Own data

* Basis: 113 people answering the questionnaire

Table 6: Chronological order of items in the washing-up process (most frequently quoted answers)*

Order number	Item
1	Glass
2	Porcelain
3	Plastic
4	Wood
5	Cutlery
6	Pots and pans

Source: Own data

* Basis: 113 people answering the questionnaire

3.2 Process

In reviewing our 113 test persons' washing-up behaviour, the dominant observation is the great variety of techniques. Many variations and combinations of processes were observed, ranging from the use of continuously running hot water over a single water bath used for all 140 articles, up to individual items being subjected to a total of four water baths (soaking, preliminary cleaning in water, cleaning in water with cleanser, rinsing in pure water). Moreover, many test persons varied their washing-up behaviour in accordance with the level of soiling and/or the number of items to be cleaned. But almost all persons had something like their 'own way' of washing up. To demonstrate these different practises, protocols of the washing-up process were made for a number of test persons on the basis of the video recordings of their washing-up activities and are reported here as case reports:

Case 1

Practise: The dish washing process begins with the test person placing a pile of plates (approximately 10 each) in the sink and continues to clean same under very little warm rinsing water (approximately 0.5 l/min). She uses a sponge with minimally applied detergent. Purposely the water is dripped from the plate being cleaned onto the remaining pile of plates in the sink to moisten same. Plates with persistent soiling are returned to the pile and the cleansing process is continued

with another plate. Cleaned plates are placed in the empty sink to the right.

Persistent soiling is at once spotted whilst attempting to clean the first glass. Immediately all glasses are filled with hot water and returned. The cleaned plates are then individually rinsed under running water, opening the water tap for merely 1 to 2 seconds. All other plates are similarly cleansed: the sink is filled with as many parts as possible and splashed with the water stemming from the cleansing process, then continuously, but with sparsely running water by means of a sponge or cleaned by hand, in the right hand sink stored intermediately and finally and again under running water finish rinsed, whereby the water tap is opened and closed for each individual part. Components difficult to clean and on which residues are detected are returned to the cleansing sink to be washed again. Cutlery is partially rinsed in bundles by simply holding several parts in one hand under running water. Other cutlery components – especially those with visible soiling – are cleaned like all other components.

Also individual dishes are dipped at times in the right hand sink filled with water floating too. Finally the glasses are cleaned following the same cleaning procedure. Dishes with residual soiling detected during towelling are returned to the cleansing sink to be cleaned once again. Cleaning detergent is sparingly used and always directly applied to the cleaning sponge.

Observation: The test person is altogether a good example for an economical handling of water and cleaning detergent within the category of 'running tap water washer', however, with an insufficient cleaning result.

Characterization: Female Czech, below 40 years of age; total water consumption 39.3 l; energy consumption: 0.52 kWh; accumulated dish washing time: 77 min; detergent consumption: 9 g; cleaning index: 2.85.

Case 2

Practise: The test person starts dish washing by carefully adjusting the water temperature and an ample application of detergent to the left hand sink. Her intention to begin with the cleaning of glasses is obviously hindered by some difficulties. In consecutive order she tries the various dish washing utensils and meticulously inspects visually the cleaning result. The washed glass is then directly placed onto the drip tray. The following four glasses are filled with hot water and placed next to the sink for soaking. The right hand sink is now filled with hot water (without detergent) and the remaining glasses soaked therein. The glasses are cleaned one after the other and placed on the drip tray without being disturbed by the partly excessive foam residues. However, sometimes lye is taken by hand from the sink and trickled onto the dishes. This procedure is applied to all dishes: Simultaneously soaking many parts in clear warm water in the right hand sink, sponge cleaning with detergent individual components in the left hand sink and transferring same to the drip tray. Only cutlery and smaller parts are placed bunch-wise into the dish water. For cleaning cutlery three to five parts are

WISSENSCHAFTLICHER BEITRAG

Table 7: Problems and disadvantages of washing-up by hand*

Problems or disadvantages	Agreement (multiple answers allowed)
Requires too much mechanical work	52 %
Cleaning result sometimes insufficient	51 %
Bulky items difficult to wash	40 %
Water and energy consumption too high	34 %
Ergonomic problems with height of sink	19 %
Other problems	8 %
No problems	3 %

Source: Own data

* Basis: 113 people answering the questionnaire

simultaneously picked up with the left hand and successively cleaned. With the exception of spinach soiled plates no post cleaning takes place. Spinach soiled plates are rinsed for post cleaning (opening the water faucet for about two to three seconds, amounting to approximately 50 ml of cold water). The excessive amount of foam created at the beginning of the process soon diminishes not causing any concern to change the dish water or to add detergent. Altogether, the water was exchanged five times in the cleansing sink and three times in the soaking sink (once with detergent). If residues were detected on dishes during towelling they were returned to the cleansing sink or separately cleaned.

Observation: The test person dealt sparingly with water and energy in spite of an intensively applied soaking procedure and produced an overall acceptable result.

Characterization: Female German, below 40 years of age; total water consumption: 48.9 l; energy consumption: 1.27 kWh; accumulated dish washing time: 83 min; detergent consumption: 15 g; cleaning index: 3.58.

Case 3

Practise: The test person starts dish washing by filling the right hand sink modestly with water and little detergent. First the glasses are to be cleaned. After quickly realizing the persistence of the staining, all glasses are filled with lye and set aside. All utensils, including fingers, are tested on the first glasses to achieve a proper result. The result is visually inspected intermittently by briefly rinsing the glasses under running water and removing residual soiling. Following the cleaning of the glasses the plates are pre-cleaned in the same dish water (especially those with spinach soiling) and placed aside. Now the dish water is exchanged again using little water and detergent. Next all cups are filled with some dish water and set aside, thereafter individually washed followed up with rinsing them under very sparingly running tap water. For this the tap is opened for a few seconds with one hand whilst the other hand places the dishes under the running water. The other dishes are treated similarly always involving a pre-soaking. The actual cleaning process is mostly rapidly executed. Some plates are placed on the drip tray

without rinsing under running water, some are rinsed. The cutlery is altogether placed in the sink with dish water. Individual parts are taken out and briefly sponge-cleaned and collected in one hand until a bunch of approximately a dozen is formed. This hand full of cutlery is then collectively and briefly rinsed under sparsely running water and sorted into the drip tray. This is accompanied by a visual cleanliness inspection and an eventual post finger cleaning.

Observation: Altogether this test person practised an almost extremely frugal version of dish washing, however, achieved a surprisingly good dish washing result due to the multiple re-use of water.

Characterization: Female German, below 40 years of age; total water consumption: 28.7 l; energy consumption: 0.26 kWh; accumulated dish washing time: 96 min; detergent consumption: 11 g; cleaning index: 3.35.

Case 4

Practise: The test person uses both sinks in a very systematic way, filling the right hand sink with hot water only and cleaning detergent for storing there firstly the dishes kind-wise, followed by rapid and powerful cleaning strokes with the cleaning sponge. The thus cleaned dishes are then placed in the left hand sink filled with cold water. After all dishes of a kind are washed other dishes are placed in the right hand sink followed by shaking the dishes deposited in the left hand sink, removed and placed on the drip pan or the already dripped once, wiped dry with a tea towel. In this way the still stained dishes remain for a maximum of time in hot dish water before same are cleaned. The same procedure is applied to all kinds of dishes. The cutlery is taken out in bundles (approximately five) from the right hand sink and somewhat hastily wiped (with a sponge) and then also placed in the left hand sink filled with clear water. The dish washing is continued even after a quite visible greenish colouring of the dish water develops in the right hand sink, only hot water is added. Only when washing the glasses the dish water is exchanged in the right hand sink.

Observation: By way of a very systematic approach the test person finishes the dish washing in record time. However, the cleaning result was rather mediocre due to lack of care.

Characterization: Female Spaniard, over 40 years of age; total water consumption: 48.5 l; energy consumption: 1.82 kWh; accumulated dish washing time: 57 min; detergent consumption: 45 g; cleaning index: 2.72.

Case 5

Practise: The test person begins by placing all flat plates, the large plate, the cutlery and the large bowl in the right hand sink. Only thereafter she fills the large bowl only approximately half with water and adds detergent. This is followed by taking the cups, which she sponge foams with

WISSENSCHAFTLICHER BEITRAG

the dish water contained in the large bowl and places them afterwards

in the yet empty left hand sink. The glasses are filled to 2/5th with hot water and set aside. Further dishes are placed in the already packed right hand sink (dry-soaking?). The large bowl with the prepared dish water is placed on an area behind the sink. Alternatively plates, cups and glasses are briefly sponge wiped, preceded by dipping the sponge for each dish in the dish water contained in the large bowl. Washed dishes are placed in the left hand sink and from time to time rinsed under running water. The water flowing to is transferred with shovelling movements to the right hand sink, respectively accumulated in the left hand sink until same is approximately half filled.

Now a batch of still stained dishes is removed from the right hand sink and placed in this water. Shortly thereafter this batch is removed again and returned to the still packed right hand sink. After a few minutes the same procedure is repeated. Likewise the glasses are washed at least five times (with sponge or brush briefly treated), then again half filled with water and somewhere (in the packed sink or on a free area) deposited.

Observation: By way of a totally uncoordinated and chaotic dish washing procedure are all dishes subjected to a multiple relocation without achieving a visible cleaning effect. In this way is it possible to obscure the likely advantages of the basic procedure with highly concentrated detergent.

Characterization: Female Italian, under 40 years of age; total water consumption: 52.1 l; energy consumption: 1.78 kWh; accumulated dish washing time: 69 min; detergent consumption: 10 g; cleaning index: 2.24.

Case 6

Practise: The test person starts by directly filling all glasses with warm water. After adding detergent to the sponge she attempts to clean the glasses under continuously running water. Realizing the apparent setback, she tries all available cleaning utensils. Following the washing of two glasses she pours detergent in all remaining glasses and places them aside. She starts to pre-clean the glasses, fills same again with water and detergent and places them aside again. Following this the bowls are filled with water and detergent and placed to the side. A stack of plates is placed into the left hand sink and soaked with the continuously running water (and detergent). Each plate is then sponge-cleaned (occasionally applying detergent to the sponge) and placed in the right hand sink. Following this the same plates are cleaned again and again and deposited in the left hand sink. Afterwards a thorough post cleaning takes place under running water (approximately five seconds per component) and a visual cleanness inspection. The remaining crockery is treated in a similar four stage procedure. The cutlery is placed in total in the left hand sink and then individually cleaned and placed in the right hand sink. Afterwards batches of three to four components are picked up, thoroughly cleaned in the left hand sink under running water and deposited.

Observation: The dish washing practise of this test person requires an extensive effort as each component was manually handled four times. Furthermore, the awkward handling under continuously running water caused excessive resource usage.

Characterization: Spanish, female, below 40 years of age; total water consumption: 363.8 l; energy consumption: 8.7 kWh; accumulated dish washing time: 78 min; detergent consumption: 93 g; cleaning index: 3.78.

Case 7

Practise: The test person begins the dish washing procedure with immediately filling the left hand sink approximately half with warm water adding a dose of cleaning detergent. Cups and dessert plates are then put into that sink. Then the water faucet is directed over the right hand sink and the desired water temperature painstakingly adjusted. After the addition of detergent to the sponge the washing of soaked plates commences under running water (flow volume approximately 6 l/min). This being finished the thorough rinsing of thus cleaned dishes follows immediately under running water. This procedure is continued until approximately half of the pre-soaked dishes are washed. Then the process is interrupted (the water faucet is closed), further dishes are loaded into the pre-soaking sink and the cleaned plates, deposited on the drip pan, are wiped dry. Thereafter ensues again the cleaning of pre-soaked dishes until once more approximately half of the pre-soaked dishes are cleaned.

Merely the cutlery is deposited in total in the pre-soaking sink and individually sponge-cleaned under running water. A hand full of cutlery is rinsed under running water whenever several pieces of cutlery are cleaned and then deposited onto the drip pan. The glasses are cleaned using in addition to the sponge also a brush.

Observation: Due to the intensive use of pre-soaking this test person achieves a good quality cleaning index. The method of dish washing under running water, however, consumes excessive amounts of water, energy and detergent.

Characterization: Female French, under 40 years of age; total water consumption: 329.2 l; energy consumption: 7.91 kWh; accumulated dish washing time: 81 min; detergent consumption: 64 g; cleaning index: 3.65.

Case 8

Practise: The test person begins the dish washing procedure by filling the right hand sink with some warm water, puts the glasses into same and adds some detergent. She begins to clean the glasses with sponge and brush followed by rinsing same under slightly running water over the left hand sink. A very fussy optical inspection of the cleaning result often causes her to repeat the process. Following this a batch of plates is placed in the right hand sink and individually sponge-cleaned. The rinsing does not take place under running water, instead in the accumulated water of the left hand sink (the drain had been closed) by merely shaking the plates in clear water prior to depositing same onto the drip pan. All dishes are washed and rinsed in this way with the

WISSENSCHAFTLICHER BEITRAG

exception that the cleaned cutlery remains for some time in the rinsing sink before it is removed batch-wise and placed on the drip pan. Remarkable is the high number of water changes, approximately ten times for the soaking sink and a few lesser times for the rinsing sink, always starting with running water.

Observation: The dish washing process thus practised is distinguished by an optimized water management and a very systematic procedural approach.

Characterization: Female French, under 40 years of age; total water consumption: 62.8 l; energy consumption: 1.32 kWh; accumulated dish washing time: 90 min; detergent consumption: 34 g; cleaning index: 3.88.

Case 9

Practise: The dish washing procedure of this test person is distinguished by an alternative use of sinks. If one sink is used for cleaning, the other sink is utilized for soaking further dishes. For this both sinks are filled 3/5th to 4/5th with detergent-enriched water and alternatively used. Only for some plates and the cutlery the soaking sink will not serve simultaneously as the cleaning sink but in this case only for pre-cleaning followed by finish-cleaning same in the other sink. The cleaned dishes are then without being rinsed and not for the purpose of drip off either placed on the drip pan or into the drain basket.

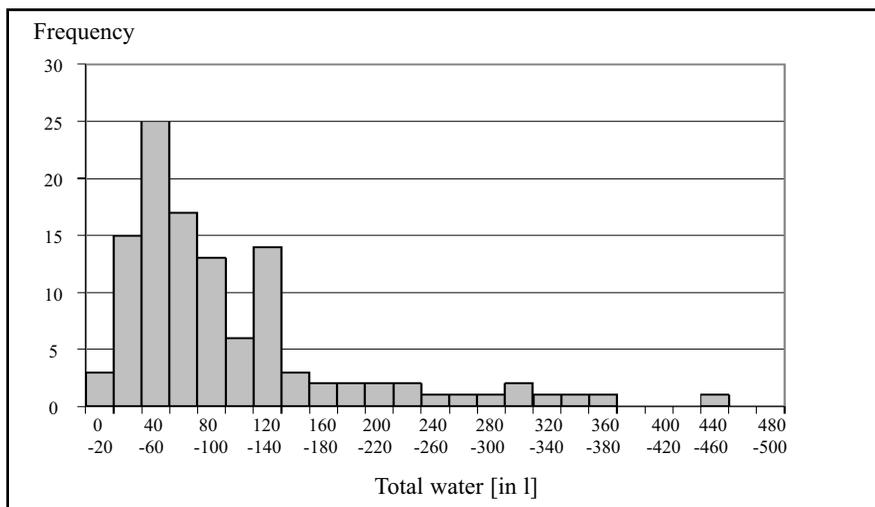
Observation: In spite of the rational use of both sinks the test person used relatively much time for doing the dishes achieving a merely moderate cleaning result.

Characterization: Female British, under 40 years of age; total water consumption: 33.0 l; energy consumption: 1.03 kWh; accumulated dish washing time: 78 min; detergent consumption: 21 g; cleaning index: 3.38.

Case 10

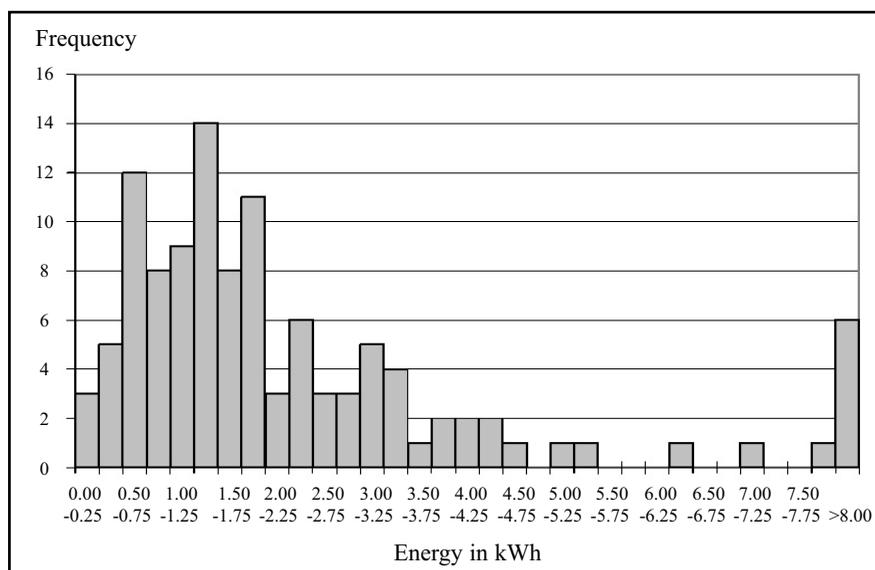
Practise: The test person starts with filling the left hand sink 4/5th with water, he adds detergent and loads the sink with spinach stained plates and bowls for soaking same. The right hand sink is filled with clear water. The procedure is started by cleaning the bowls with a sponge type cloth and depositing them in the right hand sink. The plates, however, are washed and rinsed under running water thereafter and placed on the drip pan. Afterwards the cutlery is put into the left hand sink, individually cleaned and deposited into the right hand sink. Whilst changing the water of the left hand sink the dishes deposited in the right hand sink are removed and without prior drip off immediately towelled dry. The soup plates (deep plates) are soaked and cleaned in the mean time in the left hand sink. They are placed partly direct into the drainer basket or into the right hand sink. Soaking of further plates, removing the plates from the right hand sink, dry towelling of the plates put down, cleaning of further plates are alternating work paces, failing to indicate a systematic approach. Stains detected during dry towelling are simply wiped of with the towel. Only once a plate was returned to the sink for post cleaning. Next to last the glasses are washed in accordance to the same approach whilst two brushes and the

Figure 1: Histogram of total (warm and cold) water consumption



Source: Own data

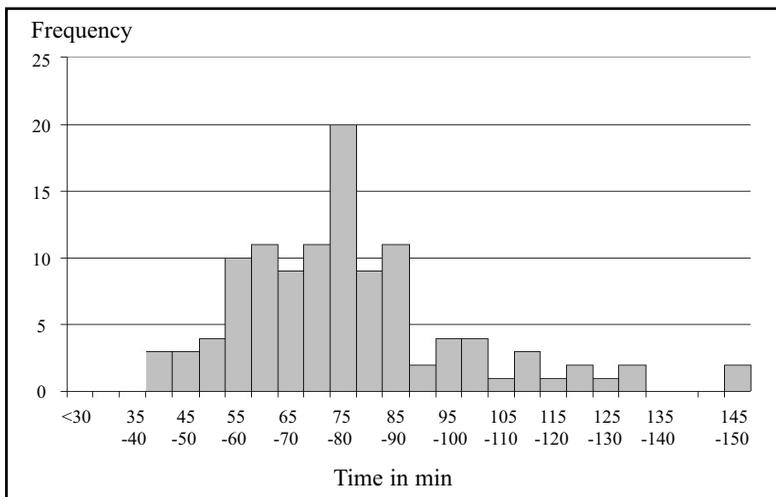
Figure 2: Histogram of total amount of energy used for all 113 manual washers



Source: Own data

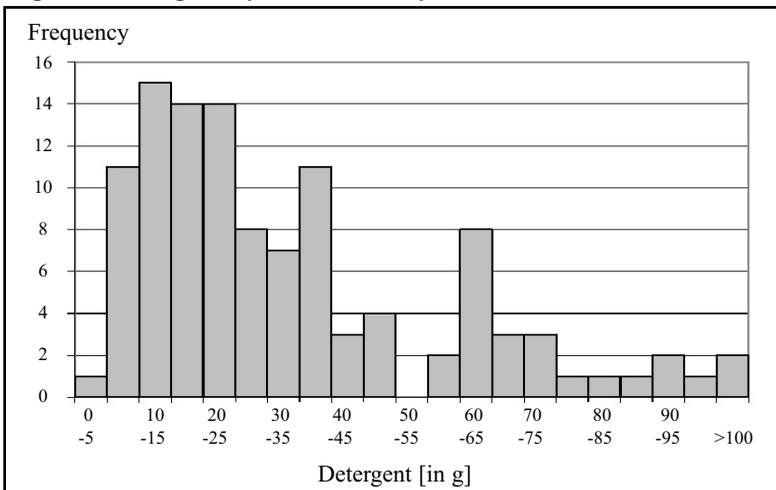
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Figure 3: Histogram of time needed for all 113 manual washers



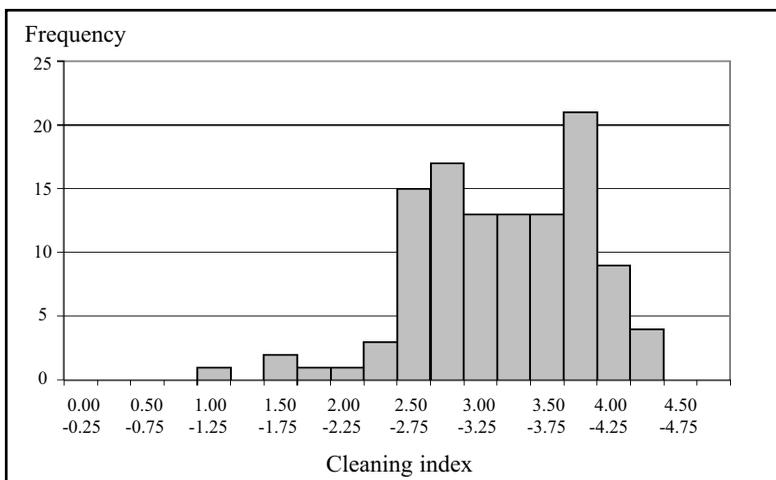
Source: Own data

Figure 4: Histogram of total amount of cleanser used



Source: Own data

Figure 5: Histogram of achieved cleaning performances



Source: Own data

Score 0 means residues area > 200 mm² on all items; score 5 means no residues on any item.

sponge type cloth are utilized. Finally the cups are washed.

Observation: With the exception of a systematic soaking the test person exhibits a rather thoughtless dish washing approach leading to a multiple change of dish water without producing a respective result.

Characterization: Male British, over 40 years of age; total water consumption: 42.4 l; energy consumption: 0.78 kWh; accumulated dish washing time: 52 min; detergent consumption: 16 g; cleaning index: 2.80.

On the basis of the above, we conclude that there is no common dish washing practise in Europe; neither can any clear preference for one technique or another be identified in any single region.

There are trends, however; for instance, running tap water seems to be used predominantly in southern European countries (France being regarded as a southern country in this context), whereas running tap water is only rarely used by test persons from European countries further north.

3.3 Measured performance and consumption of resources

The large variety of habits finds expression in the measured values of the water (Figure 1), energy (Figure 2), time (Figure 3) and cleanser (Figure 4) used. Cleaning temperature ranged from cold water use up to 54 °C, the maximum temperature offered for this test. An individual adjustment of the cleaning temperature was done by most volunteers in mixing cold and hot water supply.

Statistical methods were used to identify significant differences between averages per region for each of the measured values and the volunteers' region of origin (Table 8). Due to the relatively low number of participants, however, and due to the large variety of practises within each region, it is impossible to identify any clear clusters. Good and bad cleaners, savers and wasters can be found in all countries/regions.

Almost no differences – and definitely none of statistical significance – can be observed between the averages measured for male or female test persons. Neither were there significant differences between the averages for younger and older test persons.

Cleanness being the main aim of the whole dish washing process, the achieved cleaning performance is the most important measure for the whole washing-up process. With few exceptions, the test persons achieved cleaning performances between 2.5 and 4.5 on a scale from 0 to 5, where 5 stands for perfect cleanness. As there is no abso-

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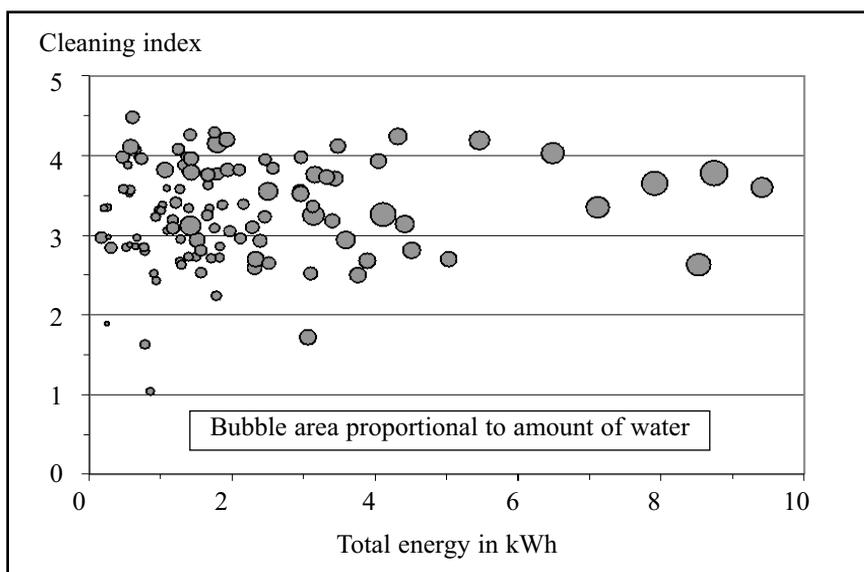
Table 8: Arithmetic average values for all regions and automatic dishwashers

Characteristics	Water [in l]	Energy [in kWh]	Cleanser [in g]	Cleaning [index]	Time [in min]
Manual dishwashing Region					
Germany	46	1.3	21	3.2	76
Poland, Czech Rep.	94	2.1	21	3.3	92
Italy	115	2.5	70	3.4	76
Spain, Portugal	170	4.7	37	3.4	79
Turkey	126	2.0	34	3.5	106
France	103	2.5	39	3.4	84
Great Britain, Ireland	63	1.6	26	2.9	65
Average of all 113 manual washers	103	2.5	35	3.3	79
Electric dishwashers (nominal values for 'normal' and 'intensive' program, except for cleaning index)	15-22	1.0-2.0	30*	3.3-4.3	Loading and unloading: ca. 15 Program time: 100-150

Source: Own data

* Different chemical composition compared to manual dishwashing liquids

Figure 6: Cleaning index, water and energy consumption of all 113 testers



Source: Own data

lute scale of what can be seen as a good or acceptable cleaning performance for manual dish washing, we followed two alternative approaches to judging the measured values: The first is to compare the results with the performance achieved by the two electric dishwashers used to clean an equivalent set of items. In a program recommended for normally soiled

dishes the machines achieved scores of 3.3 and 4.0. In their 'intensive' programs, which might be more appropriate for the level of soiling used in the tests, they scored 4.3 and 4.4 respectively. The second approach is to follow the subjective judgment of the persons doing the visual assessment: scores below about 3.5 were described as 'really dirty' or 'not acceptable on a dinner table'. Therefore we conclude that a score of 3.5 is approximately the minimum cleanness required of a dish washing process. More than half of our test persons did not achieve this level of cleanness (Figure 5). As our test persons were not asked to use the plates, glasses and cutlery themselves, they may have considered the quality of the cleaning process as unimportant. Nevertheless, a more sophisticated cleaning process would have required even more water, energy, detergent, and time! Therefore, the values measured can be regarded as conservative and as an estimate considerably lower than the corresponding values in a real-life situation.

3.4 Correlations

As has been shown before, a large variety of manual dish washing techniques was observed, with rather big differences in water and energy consumption, and also huge variations in the amount of cleanser used. Correlation analysis was used to find out if any of these resources has a dominant influence on cleaning performance. Surprisingly, none of the parameters showed up having a significant influence, beside the obvious correlation of high energy with high levels of (hot) water consumption. Good cleaning performance (higher than 3.5 and even 4.0) is achievable with small as well as large amounts of energy and/or amount of cleanser used. None of the test persons reached a cleaning performance of 4.0 or higher with less than 60 l of water (Figure 6). This seems to be one of the limiting factors for good or very good cleaning performance at the testing conditions chosen. This also goes together with the observation that frequent changes of water are needed to avoid the redeposition of soils on already cleaned items.

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4 Conclusion

This study has shown that there are significant differences in consumer behaviour and washing-up techniques, with clear consequences for the amount of resources (water, energy, time, cleanser) used. As none of the resources individually has a dominant influence on the cleaning result, differences in cleaning performance must be attributed mainly to different washing-up techniques such as soaking or clever water management, or to differences in the way and the amount of mechanical power applied.

A goal for future research should be to identify “best practises” for manual dish washing. Such best practises must ensure an acceptable level of cleaning performance while at the same time the consumption of water, energy, detergent and time should be as low as possible. But this development shall be part of our future studies.

Moreover, new dishwashers were shown to reach at least the same level of performance as almost any test person, but requiring significantly less water. Although these preliminary insights must be verified under different conditions (e.g. heavily soiled dishes, real household conditions), already electric dishwashers can be recommended as a good alternative to manual washing-up.

But emphasis should also be placed on finding ways to teach consumers the best way of washing dishes manually, as almost everybody can save considerable amounts of water, energy, cleanser, and working time immediately and without spending money on an electric dishwasher. Studying the process of washing up may also serve as a basis to learn how to lead consumers to adopt behaviour and practises that are more environmentally friendly.

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