Manual dishwashing habits: an empirical analysis of UK consumers

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Abstract

This study presents an overview of the washing up behaviour of consumers in the UK. Peoples' individual attitudes were observed as were the amount of water and energy used, the time taken and the cleaning performance. Additionally, manual dishwashing was compared with the use of automatic dishwashers. Participants were recruited to represent all geographic regions of the UK as well as forming a representative cross-section of the population. Each of the 150 participants washed a full load of soiled tableware based on the standard EN 50242 'Electric Dishwashers for Household Use – Methods for Measuring the Performance'. For comparison, the best selling dishwasher in the UK in 2007 was tested under the same conditions as those in the consumer trial. Additionally, consumers who owned a full-size dishwasher were asked to load it to the point when they decided that the dishwasher was full.

The study shows that these consumers, on average, used 49 l of water and 1.7 kWh of energy, whereas the dishwasher used 13 l of water and 1.3 kWh of energy on average for the same amount of dishes under the conditions tested. Statistical analysis showed that these differences are significant. The dishes washed by hand were found to be slightly less clean than dishes washed in a dishwasher. For washing a full dishwasher load by hand, the participants needed, on average, 60 min, while they only took 9 min on average to load and unload the same amount of dishes in a dishwasher. The average participants were able to fill almost the full load into the dishwasher (96% of the items as used in a test following EN 50242).

Introduction

Global resource consumption

Despite a decline in the birth rate of the developed world, the human population is still growing. It is estimated that in 2050, the world population will have doubled in comparison with 2005 – if fertility remains constant (United Nations, 2005). Regarding this continuous growth of the human population, the sustainable use of natural and non-renewable resources has become more important during the last decades. In the last 100 years, the global water withdrawn and the area of irrigated land have increased exponentially (Jackson *et al.*, 2001). Furthermore, data published by the World Health Organization (WHO, 1996) confirm an imbalance in the availability of water because a large part of the population does not have access to safe drinking water and basic sanitation. Similar trends can be recognized for global fossil fuels (Internal Energy Agency, 2008). Because of the increasing demand for energy, it is estimated that fossil fuels will only last for another 157 years if the global energy consumption remains constant. Additionally, increasing energy consumption will cause further environmental damage that will intensify the greenhouse effect (Fyfe *et al.*, 1993).

Household consumption

The rising demand for natural and non-renewable resources is not only limited to agriculture and industry. A significant proportion of water and energy consumption occurs in the domestic sector. About 15% of primary energy is used in private households (Energy Information Administration, 2008). One characteristic of consumption in the residential sector is that it seems to be primarily dominated 'by variability and change, with human behaviour playing a central role' (Lutzenhiser, 1993, p. 250). Therefore, it is important to understand how social processes influence the growth and demand for natural and non-renewable resources. So far, in the discussion on resource demand, human behaviour has been seen as secondary (Lutzenhiser, 1993). However, there is an urgent need for research to concentrate more on the way people act while

consuming water and energy in their private environment and on the reasons and conditions that affect their habits.

Manual dishwashing

Household consumption is spread over different areas in the domestic sector, e.g. air conditioning and a wide range of household appliances. Washing up, as one frequent household task, has been studied in different research projects before. Early studies (Sater, 1934) indicate a systematic comparison of different dishwashing methods with regard to both manual and automatic processes. Besides the time and cost factors associated with the different processes, hygiene problems and energy consumption have also been investigated in this context. More recent systematic discussions of dishwashing processes reveal that this topic remains important, although there is now more emphasis on the environmental and economic effects and consumer habits (Gutzschebauch *et al.*, 1996). Other studies include consumer tests into the systematic comparison of manual and automatic washing up. Additionally, the consumption of resources was of interest in these investigations (Luecke, 1971; Gudd *et al.*, 1994). Investigation of consumer behaviour was undertaken by Wilhite *et al.* (1995). This sociological research analyzes culture-dependent consumer behaviour in relation to energy consumption in Japan and Norway with a special focus on dishwashing. It indicates that cultural tradition has an influence on human habits, although the countries involved have similar levels and patterns of material culture.

Based on these results, additional investigations on consumers' behaviour in manual dishwashing were conducted by Bonn University, analyzing the habits of users from a number of countries across Europe. A minimum of 10 people from each country were asked to wash dishes manually under conditions that were close to those at home. This analysis does not only give an overview of the consumption values under comparable conditions, but it also provides insights in relation to how people really act and behave when washing the dishes (Stamminger *et al.*, 2007). For reasons of practicality, this European study is based on a limited number of participants and has led to biased results. The task of our study is therefore to replicate this investigation by choosing a larger and fully representative sample of participants. The results of this study can then be used to verify the already existing results about dishwashing behaviour.

The research provides insight into the dishwashing behaviour of consumers in the UK. It is based on a statistically relevant consumer sample that reflects a cross-section of the UK population. It analyzes individual attitudes but also reports on the amount of water and energy used, the time taken and the quality of cleaning. The importance of automatic dishwashers has been increasing considerably in recent years (Dolley *et al.*, 2003), and for this reason, the use of automatic dishwashers is compared with dishwashing by hand under similar conditions.

Materials and methods

Consumer tests

All tests were performed under uniform conditions close to the standard test method EN 50242:2003 (EN 50242, 2003). Accordingly, 12 standard place settings of tableware, each composed of a

dinner plate, a soup bowl, a bread and butter plate, a saucer, a cup, a glass, a fork, a knife, a soup spoon, a dessert spoon, a tea spoon and additional serving pieces, were soiled with seven different types of food, namely black tea, egg yolk, margarine, minced meat, milk, porridge and spinach. To create conditions similar to those in private households, all soiled crockery was air-dried for 2 h at $23 \pm 2°C$ and $55 \pm 5\%$ relative humidity deviant to the standard EN 50242:2003 (EN 50242, 2003). After drying, the soiled dishes were presented to the consumers. They were asked to clean and dry the dishes in the way they would normally do at home. No information was given to the consumer about any of the measurements that were being taken in order not to influence their behaviour.

Each participant was offered a range of washing up utensils, equipment and detergents for washing the dishes: diverse brands and types of dishwashing tools such as scourers, brushes, sponges and dishcloths, various brands of commercially available washing up liquid, different sized rubber gloves, a variety of draining racks, linen tea towels, and a selection of different sized and shaped plastic bowls to wash up. The washing up workstation was composed of two sinks with a drainer on either side. Because separate hot and cold water taps are still common in the UK, the consumers had the option of choosing between individual taps and one mixture tap. Unlimited hot water up to 60°C was provided by a continuous flow heater. A calibrated electronic data logging system recorded data as follows:

1 Cold and hot water consumption were taken using calibrated in-line flow meters.

2 Cold and hot water temperatures, as well as the water temperature in both sinks and of the mixture tap, were measured using thermocouples.

3 Energy consumption to heat up the water was measured. It was corrected according to the temperature of the water entering the heater so that the adjusted value was equivalent to the amount of energy that would have been used if the incoming water had been at a temperature of 15°C. This made the energy results of the manual washing up compatible with the dishwasher tests, where the feed water was also supplied at 15°C.

All data were recorded every second. Each workstation was supplied with water with a hardness of 2.5 mmol/l as this is required in the European standard. Furthermore, the quantity of washing up liquid used by each consumer was weighed. The time taken by each participant to complete their washing up session was measured from the time they first started to use the water until they had finished the washing up. This time included drying the dishes and cleaning the sink.

Before starting the test, the consumers were asked to set up the workstation in a similar format to the one they had at home, including choosing the use of individual taps or a mixture tap, positioning the draining racks to the left or right of the main sink and covering the second sink, if they normally used only one sink at home. To reflect individual habits best, the consumers were asked to dry the tableware the way they would do at home, for example drip dry the dishes, towel dry them or both. If they normally cleaned out the sink after using it at home, they were asked to do this as well. Consumption values caused by this additional cleaning process were added to the data records. During the test, the participants were left alone to avoid any interruption or influence. At the end, the cleanliness of the

Table 1 Evaluation of cleaning performance

Score	Number of small dot-shaped particles (n)	Total soiled area in mm² (A)
5	$n = 0$	A = 0
4	$0 < n \leq 4$	$0 < A \leq 4$
3	$4 < n \leq 10$	$0 < A \leq 4$
2	$10 < n$	$4 < A \leq 50$
1	Not applicable	$50 < A \leq 200$
0	Not applicable	$200 < A$

Table 2 Sample characteristics ($n = 150$)

	n (%)
Individuals per household	
1	34 (23)
2	59 (39)
3	18 (12)
4	31 (21)
5	6 (4)
6	2 (1)
Age	
18–24	10 (7)
25–34	22 (15)
35–44	36 (24)
45–54	26 (17)
55–64	25 (17)
>64	31 (21)
Gender	
Male	65 (43)
Female	85 (57)

tableware was rated visually as defined in the standard EN 50242 (2003) (Table 1).

Consumers who had a dishwasher at home were also asked to load and unload a full-size dishwasher with the same amount of dishes used for the washing up test. The aim was to load it as the users would if they were faced with these items at home. A record was made of all the items remaining when the participants decided that the dishwasher was full. In addition, for the last 20 users, the time taken to load and unload the dishwasher was also recorded.

After the practical test, each user was asked about their individual attitudes and habits about manual and automatic dishwashing in a structured questionnaire.

A user trial of 150 UK consumers took part in the research. Special efforts were made to ensure a representative sampling of the UK population by taking into account household size, age, gender, region, ethnic group and dishwasher owner for the recruitment. The composition of the sample was based on data detailed on the websites of the UK Statistics Authority and of the Office of National Statistics (UK Statistics Authority, 2007; Office for National Statistics, 2008). Participants who matched the specific criteria for this investigation were recruited by telephone from a user panel by simple random sampling. The user panel is composed of 900 volunteers and is generally used for consumer research at Intertek.

Dishwasher tests

In parallel with the user trial, a similar set of tests was carried out with an automatic dishwasher, with it being the best selling range in the UK market according to GfK[1] data for 2007. According to the standard method EN 50242:2003 (EN 50242, 2003), it was tested for cleaning performance, programme duration, and energy and water consumption. Twelve standard place settings of tableware were soiled as mentioned for the consumer tests. They were air-dried for 2 h at $23 \pm 2°C$ and $55 \pm 5\%$ relative humidity deviant to the standard EN 50242:2003 (EN 50242, 2003) as well. The detergent used for the tests was the best-selling product from the UK market as confirmed by data from Nielsen[2] in 2007. It is a multifunction product containing the detergent, the rinse aid and salt substituting ingredients in one tablet. Furthermore, no separate rinse aid was used in the testing. All tests were carried out five times using the programme recommended in the standard for energy labelling purposes.

[1]Gesellschaft für Konsumforschung, marketing research organization.
[2]The Nielsen Company, marketing research organization.

During each dishwasher run, the following data were recorded on an electronic data logging system:
• The cold water and energy consumption were measured continuously on calibrated metres.
• The cleanliness of the washed tableware was rated according to the standard method.

Results and discussion

Consumer and dishwasher tests

A representative sample of 150 UK consumers took part in this investigation. They were recruited in accordance to the National Census. The age for users to participate in this trial was 18 years up to over 64 years. Of the participants, 43% were male and 57% were female (Table 2), and 37% of the test persons were dishwasher owners.

The results of the consumer test (Tables 3 and 4, and Fig. 1) show a wide distribution of the factors: time spent, detergent use, and water and energy consumption as well as the cleanliness of the crockery. This suggests a wide range of practices in washing up. Stamminger *et al.* (2007) also found a large distribution of all consumption values for different countries.

The main aim of the dishwashing process is the visual cleanliness of the dishes. Therefore, it is the most important factor to evaluate in this process. The participants in this research achieved an average cleaning score of 3.7, showing a very wide variation of the data, with a difference of 4.7 scores between the minimum and maximum values. The distribution is right skewed. This means that the majority of the participants achieved high cleaning scores. Therefore, the median has a higher value of 3.9 than the mean. In contrast to the results of the consumer test, the dishwasher achieved a fairly constant cleaning score of 4.2 when using a programme recommended for normally soiled dishes.

Because energy is needed to supply warm water, energy consumption is highly correlated to the amount of water used. The distribution of both energy and water consumption shows a

Table 3 Statistical data of the consumption values (user trial, *n* = 150)

Parameter	Energy (in kWh)	Water (in litres)	Time (in minutes)	Cleaning score	Detergent (in grammes)
Mean	1.7	49.2	60	3.7	29.0
Median	1.4	44.1	59	3.9	23.3
Minimum value	0.4	14.1	30	0.1	4.3
Maximum value	7.1	205.8	105	4.8	93.0
25% percentile	1.1	32.3	49	3.3	15.7
75% percentile	2.1	54.6	72	4.3	35.8
Standard deviation	1.0	27.9	15	0.9	19.6
95% confidence interval					
Lower	1.5	44.7	58	3.6	25.9
Upper	1.9	53.7	63	3.8	32.2

Table 4 Statistical data of the consumption values (automatic dishwasher tests, *n* = 5)[a]

Parameter	Energy (in kWh)	Water (in litres)	Time (in minutes)	Cleaning score
Mean	1.3	13.2	152	4.2
Median	1.3	12.4	152	4.2
Minimum value	1.3	12.4	149	4.0
Maximum value	1.4	16.3	155	4.3
25% percentile	1.3	12.4	150	4.1
75% percentile	1.3	12.7	155	4.3
Standard deviation	0.0	1.7	3	0.1
95% confidence interval				
Lower	1.3	11.1	149	4.1
Upper	1.3	15.4	156	4.4

[a]Eco 50° programme.

positive bias, which means that the majority of consumers are concentrated towards lower energy and water consumption values compared with the maximum values of 7.1 kWh for energy and 205.8 l for water. On average, the participants used 1.7 kWh of energy and 49.2 l of water. In contrast to these results, the dishwasher only needed 13.2 l of water and 1.3 kWh of energy over all test runs. There is a smaller difference in the energy consumption values between the consumer test and the dishwasher test than in the water consumption values between the two. This can be explained by the larger amount of cold water used by the consumers during the washing up.

In the test, the participants were able to choose liquid detergents of different brands. No difference was made between a regular product and a washing up liquid with a concentrated formula. Even for the detergent consumption, the variation of the data is very large. The lowest amount of liquid detergent was 4.3 g, while the used maximum value was 93.0 g. Similar to energy and water use, detergent consumption shows a distribution with a positive skew, illustrating that the majority of the sample use less detergent in contrast to the maximum of the distribution.

Regarding the time the participants needed for the manual washing up, results show time values ranging from 30 min to 105 min (Fig. 1). The time measurements in the tests included cleaning the dishes and drying them with a tea towel. Because the participants were asked to behave as they would at home, some users let the dishes dry in the air instead of towel drying. However, the air drying period was not included in the time measurements

because the participants were not active during this period. This may be the explanation for some very low time values. On average, the participants needed 1 h to wash up 12 place settings, while the dishwasher who took the test needed more than twice as long.

Statistical analysis

Because of the limited number of participants per country taking part in the latest European washing up study (Stamminger *et al.*, 2007), the results tend to be biased. Therefore, to confirm the existing results about the participants' washing up practices in the UK, a statistical analysis of the different samples was carried out. Because the data are not normally distributed, the Mann–Whitney U-test was used to assess whether the two samples have the same distribution (Table 5).

The sample size of the UK study in 2003 was 27 (Stamminger *et al.*, 2007), while 150 participants took part in the actual study in 2008. Although for energy and water consumption, as well as for detergent use, the median latencies were lower, and the medians of needed time and cleaning score were higher in the samples in the UK study in 2003 than in the samples in the UK study in 2008. A significant difference for each measure cannot be dedicated for energy and water consumption, time taken and detergent use ($P > 0.05$), which means they have the same distribution. Instead, the distribution of the cleaning score in the two groups differs highly significantly ($P < 0.001$). This can be easily explained, as
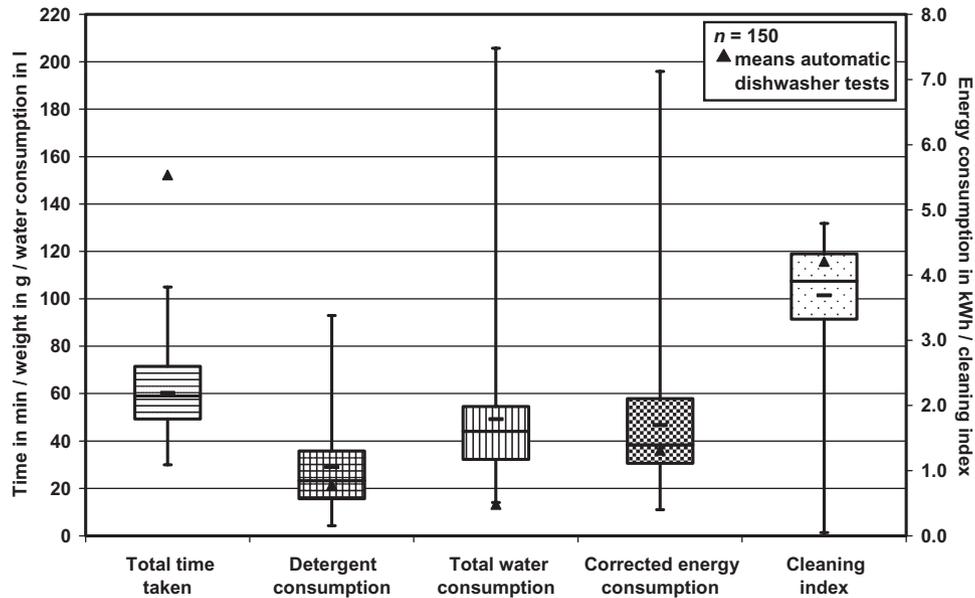
Figure 1 Statistical data of all consumption values (user trial) (mean, median, 25% percentile, 75% percentile, minimum, maximum).

Table 5 Results of the Mann–Whitney U-test

	Energy (in kWh)	Water (in litres)	Time (in minutes)	Cleaning score	Detergent (in grammes)
Median					
UK 2003 (n = 27)[a]	1.325	51.17	64	2.95	20.0
UK 2008 (n = 150)[b]	1.396	44.09	59	3.91	23.3
Test statistic U	1776	1562	1611	790	1783
Significance level (two-tailed)	0.334	0.059	0.091	0.000	0.323

[a]Sample results of Stamminger *et al.* (2007).
[b]Sample results of the actual study.

this measure is a visual one and no reference system as described in EN 50242 was used to correct the absolute readings. In summary, for all the measures except cleanliness, both samples are of the same population. So it can be concluded that even the data of the study in 2003 can be taken as an observation of the washing up behaviour of people in the UK.

Loading and unloading tests

Of the 150 users, 56 mentioned that they used a dishwasher at home. Among the 56 participants, 49 of them carried out the loading and unloading test. The time taken for this procedure was recorded for the last 20 of these participants. Altogether, the consumers spent a total of 9 min and 22 s in loading and unloading the machine on average. Regarding only the loading procedure, the consumers needed about 6 min and 27 s on average and for unloading the machine, about 2 min and 55 s on average.

In comparison with the results of the manual dishwashing tests, the participants took about 85% less time loading and unloading a full-size dishwasher load than cleaning it manually. Regarding the questionnaire, the respondents were asked how much time they would spend loading and unloading a dishwasher per day. Some 30% of the users mentioned they needed less than 5 min. In addition, about 32% of the consumers said they would spend between 6 and 10 min, and 29% take between 11 and 20 min. Only 9% think they need more than 20 min for this procedure. Comparing these results with those of the loading and unloading test, one-third of the consumers estimated the time needed correctly.

Concerning the amount of dishes the participants loaded into the dishwasher, about 33% of the consumers managed to fit all 12 place settings and serving dishes into the dishwasher. The majority (57%) left between one and 10 items out of the dishwasher, while the remaining 10% left between 11 and 20 items. In general, it can be concluded, that all the consumers utilized the dishwasher to its full potential.

Questionnaire

Following the washing up procedure, the participants were asked to complete a questionnaire. The aim is to obtain detailed background information about attitudes in relation to dishwashing. The questionnaire included both questions about manual washing up

Table 6 Importance of factors for washing up (*n* = 150)

Importance of factors when washing up	Very unimportant (%)	Unimportant (%)	Neither important nor unimportant (%)	Important (%)	Very important (%)	Do not know (%)
Low water consumption	8	9	23	32	26	3
Low energy consumption	8	6	21	31	29	4
Low consumption of detergent	10	15	20	31	20	3
Hygienic results	4	1	3	17	69	7
Cleanliness	4	1	0	13	75	7
Protection of the crockery	2	6	23	28	34	6

Table 7 Reasons for getting a dishwasher (*n* = 56; multiple response)

Reasons for getting a dishwasher	Answers (%)
Too many dishes to wash by hand	32
Dishwasher saves time	66
Dishwasher cleans better	48
Dishwasher uses less energy	13
Dishwasher uses less water	29
Recommendation	9
Dishwasher is more hygienic	41
Dishwasher was already installed	20

Table 8 Reasons for not getting a dishwasher (*n* = 94; multiple response)

Reasons for not getting a dishwasher	Answers (%)
Not enough dirty dishes	54
Buy and use is too expensive	33
Dishwasher does not clean as well as washing up by hand.	15
Dishwasher uses more energy	40
Dishwasher uses more water	35
Not enough space for a dishwasher	47
Current living situation/no opportunity	16
Do not mind washing up by hand	59

and about automatic dishwashing. General questions about the importance of different factors that deal either with dishwashing by hand or by a machine (Table 6) showed that the most important factor for the users is the visual cleanliness (75%) of the crockery. Second, hygiene results are also a major factor (69%), while 34% considered the protection of the crockery as a very important factor. Less than one-third of the respondents considered saving water, energy and detergent as very important.

The participants were asked about their reasons for owning a dishwasher (Table 7). For 66% of the participants who owned an automatic dishwasher, the main reason is saving time when using a dishwasher. Even in this context, cleanliness (48%) is the second major reason for owning a dishwasher, followed by hygienic aspects (41%), whereas 32% answered that the large amount of dishes that can be washed in a dishwasher is another reason for owning a dishwasher. Only 29% indicated water use aspects and 13% energy savings as a reason.

Asked about their reasons for not purchasing a dishwasher, 59% of the users who do not have an automatic dishwasher at home answered that they do not mind washing up by hand, while 54% of them said they do not produce enough dirty dishes (Table 8). The purchase price for a dishwasher seems to be an important factor as well. According to the results, 33% of all the users answered that buying and running a dishwasher is too expensive. Only 15% believe that a dishwasher does not clean as well as washing up by hand.

The main reason for not buying a dishwasher (75%; Table 8) is that the participants believe it needs more energy and water than washing up by hand. This view contradicts results from the question on reasons for buying a dishwasher (Table 7) where only 42% of the respondents said that ecological reasons were important for them. In general, the participants seem to be of the opinion that doing the dishes manually saves natural resources.

Table 9 What do you not like about washing up by hand? (*n* = 150, multiple response)

What do you not like about washing up by hand?	Answers (%)
It is tiring.	24
It gives me skin problems.	21
Some dishes are too large/too heavy.	17
It is time consuming.	59
Poor cleaning	11
It uses a lot of water.	18
It uses a lot of power.	11
It is dangerous.	5
There is nothing I don't like.	23
No reply	7

A similar opinion can be found in answers to the question on which method the participants think needs less water and less energy. Some 44% of the 150 participants mentioned manual dishwashing needs less water than a dishwasher compared with the 33% who believe using a dishwasher saves more water. Similarly, only 13% answered that a dishwasher needs less energy while 60% marked washing up by hand as more energy efficient. However, the results of the dishwasher test show lower values for energy, especially for water, compared with the results of the manual washing up trial (Fig. 1).

The consumers were asked about what they did not like about washing up by hand (Table 9). The three main reasons the consumers mentioned were first, manual dishwashing is time consuming (59%). Second, the consumers refer to problems with their skin (21%) on the one hand and with handling the dishes because

Table 10 Frequency of washing up by hand (users who do not own a dishwasher: *n* = 94; users who own a dishwasher: *n* = 56)

Frequency of washing up	Answers (%)	
	n = 94	*n* = 56
Two or three times a day	56	25
Once a day	32	43
Every second day	2	5
Two or three times a week	5	9
Once a week	1	5
Less frequently	1	9
Never	0	2
No reply	2	2

Table 11 Frequency of using an automatic dishwasher (*n* = 56)

Frequency of dishwasher use	Answers (%)
Two or three times a day	2
Once a day	54
Every second day	21
Two or three times a week	14
Once a week	7
Less frequently	2
Never	0

of their size or weight (17%) on the other hand. Third, 24% said that this procedure is tiring. Finally, only 18% mentioned the high water consumption, and 11% of the participants were of the opinion that doing the dishes uses a lot of power.

All of the participants, including the dishwasher owners, were asked about how often they do the dishes by hand (Table 10). Over 88% of the users who do not have an automatic dishwasher at home mentioned doing the washing up once a day or more, while 8% answered that they do the dishes between once up to three times a week. The rest do it less frequently or never. With regard to the consumers who own an automatic dishwasher, 68% of them answered doing the dishes once a day or more often, while a total of 19% responded washing up between one and three times per week. Only 11% of the dishwasher owners mentioned doing manual dishwashing less frequently or never. This distribution shows very clearly that the participants who also use a dishwasher do one wash up or more by hand every day. According to the questionnaire, 95% of the dishwasher owners also confirm that they wash up items by hand as well as using the dishwasher.

At the same time, the dishwasher owners were asked about how frequently they normally use their dishwasher (Table 11). Some 54% of the respondents said they use it once a day, while the rest said they use it between once a week and every second day (42%) or, actually, less frequently (2%). More than half of the consumers who own a dishwasher wash up items by hand every day, and more than 50% of them also use the dishwasher once a day.

The participants were asked about their preferred method of washing up. Many (29%) answered that they do the washing up only in a bowl placed in the sink or combine this method with doing the dishes under running tap water (26%). More than one-third mentioned washing up in a water-filled sink, whereas 20%

additionally use running tap water. Only 5% replied doing the dishes only under continuously running tap water. Only 13% of the volunteers said they normally soak some or all the dishes in water before they wash up by hand, but in contrast, more than 60% answered they usually rinse them after dishwashing.

Conclusion

This study describes peoples' behaviours and attitudes in relation to manual and automatic dishwashing in the UK. Therefore, a representative sample of the UK population was recruited to confirm the results of a former investigation on European washing up practices on a sounder statistical basis. As a result, it could be shown that even the results of a smaller sample can be used to obtain a sound picture of the behaviour of the population of a whole country. Because the results of this investigation are limited to UK consumers, further studies have to be conducted with user panels from different countries. Under controlled conditions, where consumers washed up 12 place settings according to the standard test method EN 50242:2003, the results of this research show a wide range of different washing up techniques between consumers even of one country. This is especially underlined by the large distribution of the consumption values in the same way as published by Stamminger *et al.* (2007). It should also be recognized that consumer behaviour in real households may differ from the findings of this laboratory test because it was performed under certain parameters. Therefore, additional research that should disclose consumers' dishwashing habits in their private environment is needed.

A survey showed that the cleanliness and hygiene aspects are the main factors that are important for consumers in the UK. In addition, time is also a consideration, while ecological aspects on energy and water savings are secondary. These findings show clearly that the issue of the sustainable use of natural and non-renewable resources has not reached all users yet. Consequently, more consumer education is needed on how to use resources such as water and energy and any other consumption items more sustainably. Therefore, further research on 'best practices' for manual dishwashing and other household tasks is required. Consumers must be educated about the consequences of their choices. However, to encourage people to change their attitudes and habits, improvements in terms of their living standards induced by a more sustainable behaviour must be communicated, especially the money- and time-saving aspects.

Machine tests demonstrated that automatic dishwashing reaches better cleaning results compared with the average results of washing up by hand on the condition that a full load of 12 place settings is cleaned. In addition, automatic dishwashing saves time and requires less energy and more importantly, less water compared with most of the consumers investigated under the chosen condition if a new machine model is used. Conclusively, in the context of sustainability, new electrical dishwashers can be recommended as a positive alternative to manual washing up.

Acknowledgement

References

Dolley, P., Oldman, L. & Poll, J. (2003) The suitability of eco-label criteria to device environmental baseline requirements applicable to all products in the market. Final Report, issue 2, AEA Technology, Culham Abingdon [WWW document]. URL http://www.anec.org/attachments/env011-03.pdf (accessed on 25 September 2009).

EN 50242 A1:2003. (2003) *Electric Dishwashers for Household Use – Methods for Measuring the Performance*. European Committee for Electrotechnical Standardization, Brussels.

Energy Information Administration. (2008) *International Energy Outlook 2008*. Energy Information Administration, Washington, DC. [WWW document]. URL http://www.eia.doe.gov/oiaf/ieo/pdf/0484(2008).pdf (accessed on 26 January 2009).

Fyfe, W.S., Powell, M.A., Hart, B.R. & Ratanasthien, B. (1993) A global crisis: energy in the future. *Natural Resources Research*, **3**, 187–196. [WWW document]. URL http://www.springerlink.com/content/p673776641387451/fulltext.pdf (accessed on 26 January 2009).

Gudd, R., Kionka, U. & Schmitz-Plaskuda, R. (1994) *Vergleich der Wirtschaftlichkeit zwischen dem Handspülen und dem Spülen mit der Geschirrspülmaschine* (ed. by R.W.E. Energie). Versuchsbericht, Essen.

Gutzschebauch, C., Härer, J., Jeschke, P., Schröder, R. & Zaika, D. (1996) Geschirrspülen von Hand und in der Maschine – ein System-vergleich. *Hauswirtschaft und Wissenschaft*, **2**, 51–63.

International Energy Agency. (2008) *Key World Energy Statistics 2008*. International Energy Agency, Paris. [WWW document]. URL http://www.iea.org/textbase/nppdf/free/2008/key_stats_2008.pdf (accessed on 26 January 2009).

Jackson, R.B., Carpenter, S.R., Dahm, C.N., McKnight, D.M., Naiman, R.J., Postel, S.L. & Running, S.W. (2001) Water in a changing world. *Ecological Applications*, **4**, 1027–1045. [WWW document]. URL http://www.jstor.org/stable/3061010?origin=JSTOR-pdf&cookieSet=1 (accessed on 26 January 2009).

Luecke, A. (1971) Hausfrauen im Wettstreit mit dem Geschirrpuller. *Haustechnischer Anzeiger*, **6**, 117–118.

Lutzenhiser, L. (1993) Social and behavioral aspects of energy use. *Annual Review of Energy and the Environment*, **18**, 247–289. [WWW document]. URL http://arjournals.annualreviews.org/doi/pdf/10.1146/annurev.eg.18.110193.001335 (accessed on 26 January 2009).

Office for National Statistics. (2008) *Mid-2006 UK England & Wales, Scotland and Northern Ireland*. [WWW document]. URL http://www.statistics.gov.uk/statbase/Product.asp?vlnk=15106 (accessed on 26 January 2009).

Sater, V.E. (1934) Time and cost evaluation of dishwashing by different methods. *State College of Washington Agricultural Experiment Station Bulletin*, **303**, State College of Washington Agricultural Experiment Station, Pullman.

Stamminger, R., Elschenbroich, A., Rummler, B. & Broil, G. (2007) Washing-up behaviour and techniques in Europe. *Hauswirtschaft und Wissenschaft*, **1**, 31–40.

UK Statistics Authority. (2007) *UK Statistics Authority*. [WWW document]. URL http://www.statistics.gov.uk/census2001/pdfs/standard_tables_final.pdf (accessed on 13 November 2008).

United Nations (UN). (2005) *World Population Prospects, The 2004 Revision, Highlights*. United Nations, New York. [WWW document]. URL http://www.un.org/esa/population/publications/WPP2004/2004Highlights_finalrevised.pdf (accessed on 30 October 2008).

Wilhite, H., Nakagami, H., Takashi, M. & Yamaga, Y. (1995) A cross-cultural analysis of household energy use behaviour in Japan and Norway. *Energy Policy*, **9**, 795–803.

World Health Organization. (1996) *Water Supply and Sanitation Sector Monitoring Report: Sector Status as of 1994*. WHO/EOS/96.15. World Health Organization, Geneva.