

## WISSENSCHAFTLICHER BEITRAG

# Dishwashing Under Various Consumer-relevant Conditions

Rainer Stamminger / Britta Rummler / Anja Elschenbroich / Gereon Broil

*Until recently, comparisons of manual and automatic dishwashing used to be limited almost exclusively to the washing of large enough amounts of dishes to fill a normal domestic dishwasher. The usefulness of such comparisons is limited because such large amounts of dishes are rarely used by average households in a single meal. A much more practice-oriented approach is to compare the frequent manual washing of smaller amounts of dishes – such as are soiled in a normal household during breakfast, lunch or dinner, together with heavily soiled cooking utensils used in food preparation – with the automatic washing of the same load in a dishwasher. That is exactly the approach taken in the research for the present study, which is based on 46 test persons. The test design made it possible to compare the results with earlier findings from research with larger amounts of dishes. The main results are that the washing of smaller amounts of dishes by no means reduces the specific consumption of resources and that the washing of pots and pans is a significant contribution to the consumption of resources. In a comparison with the washing of the same load in a dishwasher, electric dishwashers have a clear advantage over manual dishwashing both in terms of cleaning performance and in terms of the amount of water used. Demonstrating surprisingly good levels of repeatability by the individual test persons, the tests also allowed comparisons of the efficiency of different washing-up liquids.*

## 1 Introduction

This study is a continuation of our investigation (Stamminger et al. 2007) of consumer habits and practices regarding dishwashing in European households. In those previous studies we saw that a broad distribution of

practices was associated with the manual dishwashing processes of the 113 participating European inhabitants, and we found out that dishwashers can do the job in a better (meaning cleaner) and more efficient (meaning lower consumption of water and energy) way. But those studies concentrated on the washing of a large number of items at the same

time, and they only took ‘normally’ soiled dishes into account.

There have not been any investigations yet dealing with how practices change if a smaller amount of dishes has to be cleaned or if soils are more persistent, as is often the case with cooking equipment. These are relevant questions because in manual dishwashing it is not common practice to wait until a huge amount of soiled dishes has assembled before washing up. Brokjans (Brokjans 1994) has found that in the vast majority of households in Germany dishes are washed manually once or even more than once per day (Table 1). This observation was confirmed by the answers given (Table 2) in the first part of our investigation, in which 113 persons from almost all over Europe were asked about their manual dishwashing frequency. Only a minority of 14.2 % washed their

### Geschirrspülen von Hand und in der Maschine unter verschiedenen verbrauchernahen Bedingungen

*Der Vergleich des Geschirrspülens per Hand und in der Maschine hat sich bisher fast ausschließlich auf das Spülen einer so großen Geschirrmenge beschränkt, wie sie komplett in einer normalen Geschirrspülmaschine Platz findet. Diese Gegenüberstellung ist insofern problematisch, als in einem Durchschnittshaushalt selten zur gleichen Zeit eine so große Menge an Geschirr anfällt. Viel praxisnäher ist der Vergleich zwischen dem häufigen manuellen Spülen kleiner Geschirrportionen – wie sie in einem üblichen Haushalt beispielsweise beim Frühstück, Mittagessen und Abendessen anfallen, zusammen mit stark angeschmutztem Kochgeschirr von der Essenszubereitung – mit dem maschinellen Spülen dieser gesammelten Geschirrmenge in einer Spülmaschine.*

*In der vorliegenden Arbeit wird genau dieses an Hand von 46 Probanden aus Europa untersucht, wobei es das Testdesign erlaubt, die ermittelten Ergebnisse mit den schon vorher erhaltenen Ergebnissen zum Spülen einer großen Geschirrmenge zu vergleichen.*

*Als Ergebnis stellt sich heraus, dass das Reinigen kleiner Mengen an Geschirr keineswegs mit geringerem spezifischem Ressourceneinsatz verbunden ist und auch das Spülen von Töpfen und Pfannen erheblich zum Ressourcenverbrauch beiträgt. Im Vergleich zum Spülen derselben Geschirrmenge im Geschirrspüler ergeben sich hinsichtlich der Reinigungsleistung und insbesondere der eingesetzten Menge an Wasser auch unter diesen Bedingungen Vorteile für den Geschirrspülautomaten.*

*Die Versuche zeigen eine überraschend gute Wiederholbarkeit durch die einzelnen Probanden und ermöglichen damit, verschiedene Handspülmittel auf ihre Effizienz hin zu vergleichen.*

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Table 1: Frequency of manual dishwashing per week

| Frequency | Percentage | Frequency | Percentage |
|-----------|------------|-----------|------------|
| 1 x       | 5 %        | 9 x       | 1 %        |
| 2 x       | 7 %        | 10 x      | 1 %        |
| 3 x       | 7 %        | 14 x      | 11 %       |
| 4 x       | 6 %        | 21 x      | 15 %       |
| 5 x       | 1 %        | 28 x      | 1 %        |
| 7 x       | 43 %       | 35 x      | 1 %        |
|           |            | 42 x      | 1 %        |

Source: Brokjans 1994; n = 100

Table 2: Frequency of manual dishwashing as stated by test persons

| Frequency                                | Percentage   |
|------------------------------------------|--------------|
| Every two or three days                  | 14.2         |
| Once per day                             | 23.9         |
| Twice per day                            | 17.7         |
| After each meal                          | 31.0         |
| Before and after cooking                 | 3.5          |
| As soon as a piece of crockery is soiled | 9.7          |
| <b>In total</b>                          | <b>100.0</b> |

Source: Stamminger et al. 2007

Table 3: Number of dishes used per day in relation to household size

| Meal                                 | Number of persons per household |           |            |            |
|--------------------------------------|---------------------------------|-----------|------------|------------|
|                                      | 1                               | 2         | 4          | 6          |
| Breakfast                            | 6                               | 12        | 24         | 36         |
| Warm lunch incl. starter and dessert | 8                               | 16        | 32         | 48         |
| Cold supper incl. drink              | 5                               | 10        | 20         | 30         |
| Snack (fruit, cold drink, etc.)      | 1                               | 2         | 4          | 6          |
| Snack (e. g. hot drink and cake)     | 5                               | 10        | 20         | 30         |
| <b>Total</b>                         | <b>25</b>                       | <b>50</b> | <b>100</b> | <b>150</b> |

Source: KTBL 1998 (translated by the author)

dishes less than once per day. Depending mainly on household size and on how often people eat out, in most households the number of items which are used and must be cleaned per day will be smaller than the number of items used in our previous test (140 items) (Table 3). A normal two-person household may need only about half of a normal dishwasher's capacity per day for normal dishes, using the remaining capacity for bulky cooking utensils. When placed in a dishwasher, they can be a challenge for the machine in two regards: firstly they take up a lot of space in the dishwasher basket and secondly they are more heavily soiled than normal dishes, glasses or cutlery.

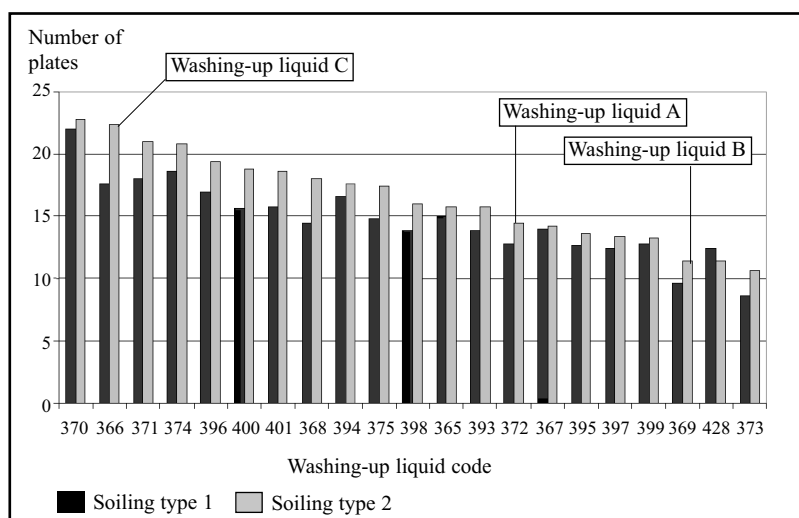
Another condition of the first investigation may be argued not to have been very consumer-relevant: the test persons were free to choose a washing-up liquid from a wide range of products from many countries. Therefore, some products may have supported the cleaning process better than others, leading to lower time, energy or water consumption or resulting in better cleaning performance. This hypothesis is supported by comparative tests of washing-up liquids available on the German market (Schmitz-Günther 2003) which showed big dif-

ferences in efficiency (Fig. 1). But the test procedure for this kind of test (Nitsch, Hüttmann 2002) is based on liquid soiling which is not really dried onto the items to be cleaned.

Therefore, the aim of the investigation of manual dishwashing described here was to check if our results would be confirmed under more consumer-relevant conditions, i. e. with smaller loads and heavily soiled cooking utensils. Another aim was to assess the influence of different washing-up liquids on the efficiency of the dishwashing process. In all this, our objective was to work with volunteers reflecting the differences in dishwashing behaviour seen in the previous study. Finally, manual dishwashing under these conditions was to be compared with automatic dishwashing.

In summary, our intention was to simulate the dishwashing situation in a two-person household, in which two place settings are used and cleaned three times per day (bre-

Figure 1: Cleaning performance of washing-up liquids



Source: Standard test procedure according to Nitsch and Hüttmann (2002); data according to Schmitz-Günther (2003).

Products A, B and C represent a mean, a poor and a good performance, respectively.

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Table 4: Cooking items and soiling

| Item      |                        |               |              | Soiling              |                  |                        |
|-----------|------------------------|---------------|--------------|----------------------|------------------|------------------------|
| Form      | Model                  | Size          | Manufacturer | Type                 | Provider, source | Preparation            |
| Pan       | Bratfix<br>NovoGrill   | 26 cm         | Fissler      | Lasagne              | Alberto          | Instruction on package |
| Pot       | Top-Line               | 16 cm, 1.3 l  | Steinbach    | Scrambled eggs       | Fresh eggs       | Own cooking experience |
| Casserole | Ceramics               | 17 cm x 17 cm | Steinbach    | Oatmeal              | Sta-De 2006      | EN 50242:1998          |
| Casserole | Glass Classic<br>Pyrex | 30 cm x 20 cm | Steinbach    | Minced meat with egg | Sta-De 2006      | IKW 1998               |

Source: Own representation

akfast, lunch, dinner) and four additional items are soiled heavily in the food preparation processes and are washed separately. For purposes of comparison, a normal dishwasher was to be operated once with all of the above items.

## 2 Materials and Methods

As in the first investigation (Stamminger et al. 2007), the tests were performed under conditions that were as identical as possible for all volunteers, and they again followed EN 50242, an internationally accepted standard for the testing of dishwashers (EN 50242:1998). It specifies clearly the dishes, glasses and cutlery to be used, and it provides detailed instructions for soiling these articles with minced meat, oat flakes, spinach, margarine, tea, egg and milk (all from one source (Sta-De 2006)).

To simulate smaller loads, six place settings (three times two; each place setting consisting of a soup plate, a dinner plate, a dessert dish, a cup, a saucer, a glass, a fork, a knife,

a soup spoon, a teaspoon, a dessert spoon) were used and soiled at the same time.

Additionally, one small plate was added to each pair of place settings in order to make up for the serving bowls prescribed in the standard for a complete dishwasher load but left out in the tests. These additional plates were soiled with spinach according to the test procedures.

The drying of the soiled dishes was not carried out according to EN 50242 because the stipulated two hours in a drying cabinet at 80 °C are unrealistically extreme for manual dishwashing. Therefore, the soiled dishes were dried at ambient conditions for two hours.

The 'heavily soiled' items specified by the test procedures are four cooking utensils such as are commonly used in food preparation (Table 4). They were soiled with lasagne, scrambled egg, oatmeal and minced meat and left on a heating plate or in an oven until a brown coating formed. After this burning-on process, all items were allowed to cool down to ambient temperature before they were used in the dishwashing test.

Table 5: Origin of volunteers for dishwashing test

| Country of origin | Number of persons |
|-------------------|-------------------|
| Germany           | 22                |
| Poland            | 4                 |
| Spain             | 11                |
| Italy             | 2                 |
| Greece            | 1                 |
| Portugal          | 2                 |
| Turkey            | 4                 |
| <b>Total</b>      | <b>46</b>         |

Source: Own representation

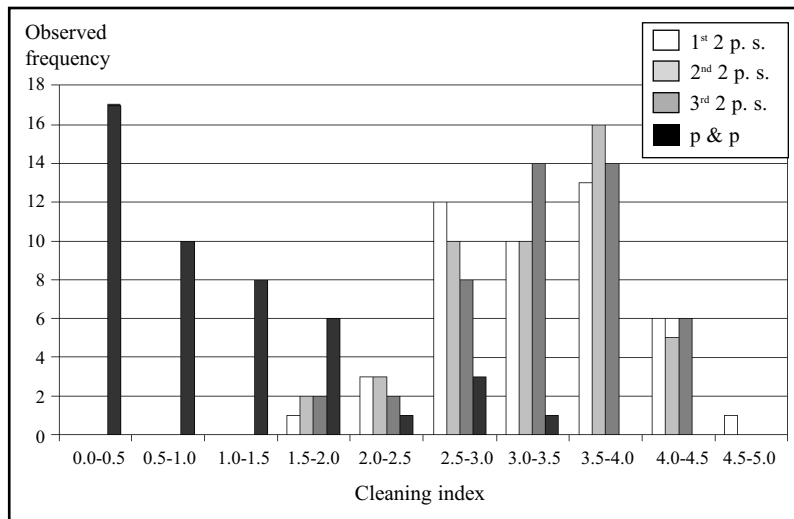
Table 6: Estimated European average consumption values and time for cleaning one place setting (11 items) or one pot or one pan at a time

| Study          | Number of participants | Objects cleaned (number, kind) | Water in l | Energy in kWh | Time in min | Cleanser in g |
|----------------|------------------------|--------------------------------|------------|---------------|-------------|---------------|
| <b>Part</b>    |                        |                                |            |               |             |               |
| Place settings |                        |                                |            |               |             |               |
| 1              | 113                    | 12 place settings              | 8.6        | 0.21          | 6.6         | 2.9           |
| 2              | 46                     | 3 x 2 place settings           | 10.1       | 0.21          | 8.6         | 3.8           |
|                |                        | <i>Weighted average</i>        | <i>9.0</i> | <i>0.21</i>   | <i>7.2</i>  | <i>3.2</i>    |
| Pots and pans  |                        |                                |            |               |             |               |
| 2              | 46                     | 4 pots and pans                | 5.6        | 0.13          | 4.0         | 3.2           |

Source: Own representation

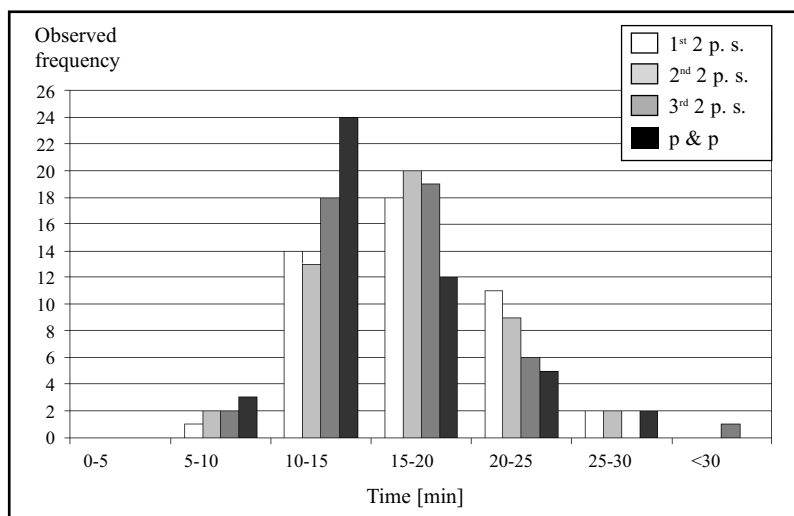
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Figure 2: Distribution of cleaning index 'place settings (1<sup>st</sup>, 2<sup>nd</sup> and 3<sup>rd</sup> run)' and 'pots/pans'



Source: Own representation

Figure 3: Distribution of time needed 'place settings (1<sup>st</sup>, 2<sup>nd</sup> and 3<sup>rd</sup> run)' and 'pots/pans'



Source: Own representation

EN 50242 also provides clear instructions as to how cleaning performance is to be assessed: depending on the number or total size of soil spots, items are given a rating from 0 (more than 200 mm<sup>2</sup> of soil) to 5 (no soil left). More details are given in the standard (EN 50242:1998) and elsewhere (Stamminger et al. 2007; Rummler 2005).

Three different brands of washing-up liquid were used (products A, B and C). According to tests following other test procedures (Schmitz-Günther 2003), they are characterised by superior, average and insufficient efficiency (Fig. 1). All three products have so-called 'concentrated formulations' and are recommended to be used in the same dosage. It was made sure that the packages used in the tests were all from the same production batches for each of the three brands.

Every test person had to wash two place settings with each of the washing-up liquids. To avoid any influence of mental or physical exhaustion, the order in which the three brands were used was varied systematically, and the test persons were given 15-minute breaks between experiments. In the next step, the cleaning of heavily soiled cooking items, the test persons were free to choose the washing-up liquid they preferred. Throughout these four steps, the volunteers were free to use whatever washing-up tools they preferred.

During the washing-up process, data on time, energy and water consumption were recorded by means of a data-logging system, and afterwards the cleaning performance was assessed as described above (for further details see Stamminger et al. 2007). The washing-up liquid consumption was recorded individually for each of the four steps, and so was their choice of a washing-up liquid in the last step, the washing of heavily soiled articles.

46 persons altogether participated in this study. Reflecting the findings from the previous study, an attempt was made to achieve a broad representation of people from many nations from all over Europe (Table 5). As in the previous experiment, the volunteers were again asked to wash up in the way they usually would at home.

In parallel to these tests, two commercially available electric dishwashers were run under conditions that were as similar to the above conditions as possible, which means they were loaded with the six place settings of soiled items and three extra dishes stipulated in the standard plus four heavily soiled cooking utensils. In accordance with EN 50242, the dishwashers were operated in the programme for heavily soiled articles (called 'intensive'). This was repeated four times. The cleaning performance was assessed visually, but the consumption values were taken from the instruction manuals.

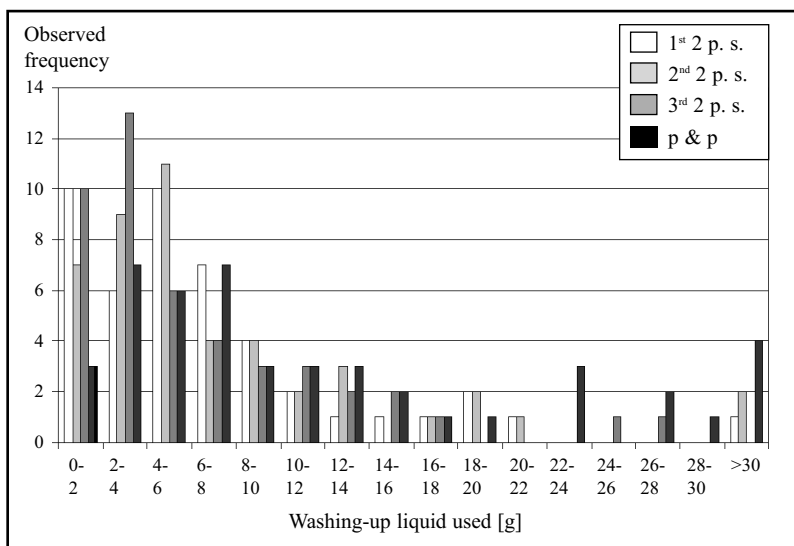
## 3 Results and Discussion

### 3.1 Small and heavily soiled loads

The distribution of the cleaning performances achieved (Fig. 2) for each pair of place settings remained very similar throughout all three runs, which shows that there were no exhaustion effects. By contrast, the average cleaning efficiency achieved was slightly higher than in our preceding experiments, in which each test person had washed 12 place settings at a time. Thus, lower exhaustion levels of the test persons may have resulted in better concentration on the cleaning process itself.

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Figure 4: Distribution of amount of washing-up liquid 'place settings (1<sup>st</sup>, 2<sup>nd</sup> and 3<sup>rd</sup> run)' and 'pots/pans'



Source: Own representation

For the heavily soiled items the cleaning efficiency was not as good as for the place settings: almost all test persons left large-scale residues on the washed items.

Time consumption was also very similar for all three runs (Fig. 3). Washing four heavily soiled items took as much time as washing a set of 23 pieces of normally soiled dishes, glasses and cutlery (equals two place settings).

The washing-up liquid consumption (Fig. 4) was also similar for all three runs with place settings, but the test persons tended to use more washing-up liquid in washing the four heavily soiled articles.

The water and energy measurements (Fig. 5 and 6) again show a very wide distribution of consumption values, ranging from four to 90 l and from 0.03 kWh up to 2.6 kWh for washing a pair of place settings. Again, washing four heavily soiled cooking items required slightly more energy and water than two place settings.

All test loads (6 place settings of dishes, cutlery and glasses plus three extra plates and four heavily soiled items) were cleaned together in two dishwashers five times each. The average cleaning performance achieved was 4.06 and 4.12, but for the heavily soiled items the ratings were 1.95 and 1.6, which is better than what three-quarters of our test persons achieved by manual cleaning! The consumption values for these intensive programs are reported to be about 20 l of water and 1.6 to 2.0 kWh of electrical energy.

### 3.2 Effect of number of items to be cleaned

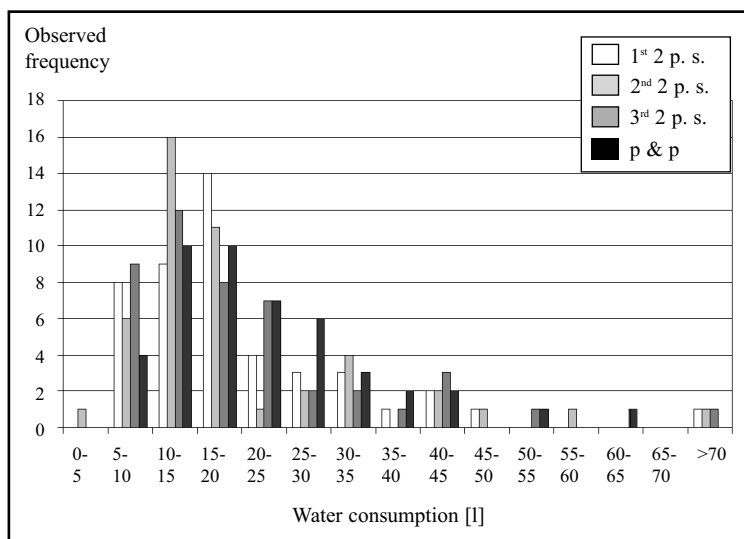
Although this and the preceding study were carried out with different test persons, it is possible to

compare the amounts of water and electricity used in households for washing larger or smaller amounts of dishes or for washing heavily soiled pots and pans. By multiplying the amounts of resources used in cleaning two place settings by six it is possible to draw a comparison with the cleaning of 12 place settings in a row. In addition, the daily consumption of a two-person household having three meals per day can be calculated by multiplying the amounts of water and electricity consumed in cleaning two place settings by three and adding the water and electricity consumed in cleaning the corresponding pots and pans. These scenarios may be additionally compared with automatic dishwashing.

The outcome of this comparison is that the average water consumption (Fig. 7) for cleaning 12 place settings is more than 121 l if the load is divided into smaller portions (six times two place settings), whereas the average consumption for the same load washed in one go is only 103 l. With a more realistic load of three times two place settings plus pots and pans, the total water consumption drops to 83 l on average. Regardless of the composition of the load to be washed and the dishwashing frequency in a household, all water consumption values for manual dishwashing are much higher than those of a modern electric dishwasher loaded with the same items.

With regard to energy consumption (Fig. 8), the tendencies are similar, but the difference between manual and automatic dishwashing is not as pronounced. However, the kind of energy used and the corresponding energy losses for both processes will be of a different nature (electricity for automatic dishwashers and usually gas or oil for manual dishwashing) so that comparisons depend on many other factors.

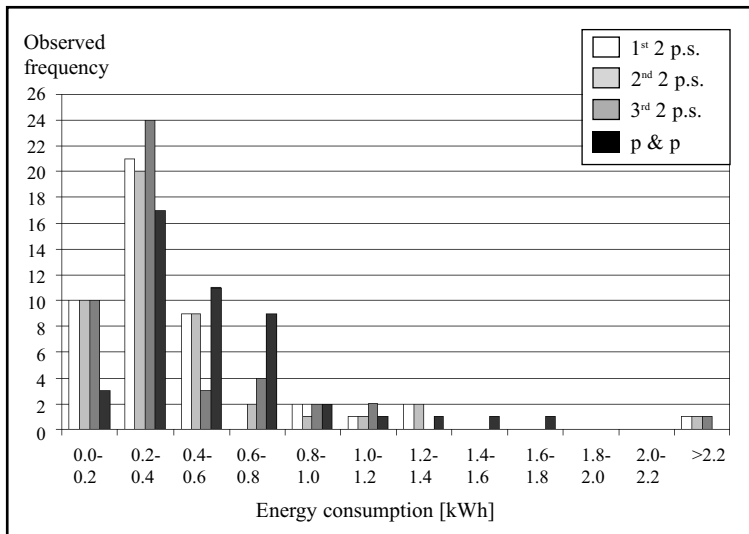
Figure 5: Distribution of amount of water used 'place settings (1<sup>st</sup>, 2<sup>nd</sup> and 3<sup>rd</sup> run)' and 'pots/pans'



Source: Own representation

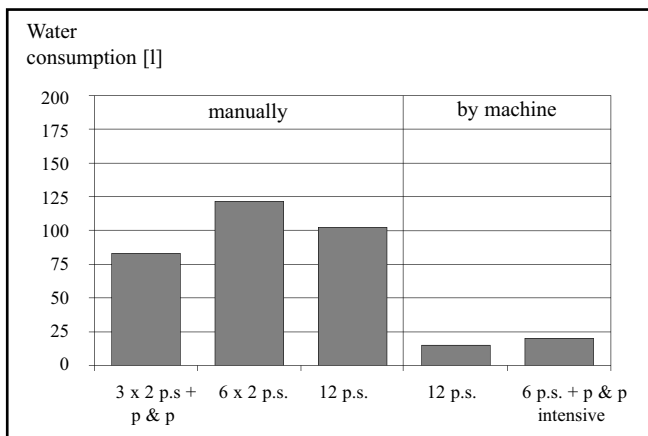
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Figure 6: Distribution of amount of energy needed 'place settings (1<sup>st</sup>, 2<sup>nd</sup> and 3<sup>rd</sup> run)' and 'pots/pans'



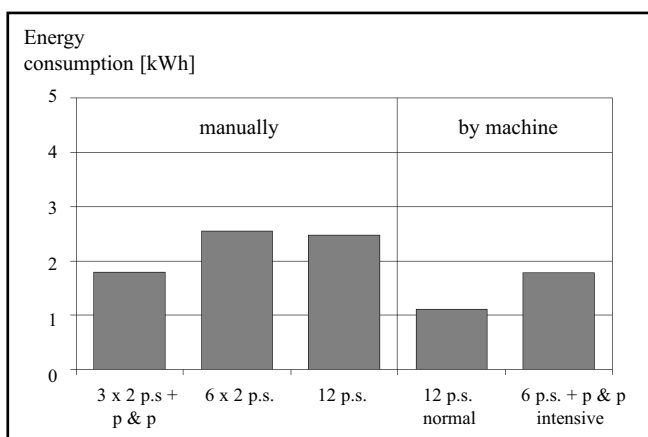
Source: Own representation

Figure 7: Comparison of water consumption for a full dishwasher load washed manually or by machine



Source: Own representation

Figure 8: Comparison of energy consumption for a full dishwasher load washed manually or by machine



Source: Own representation

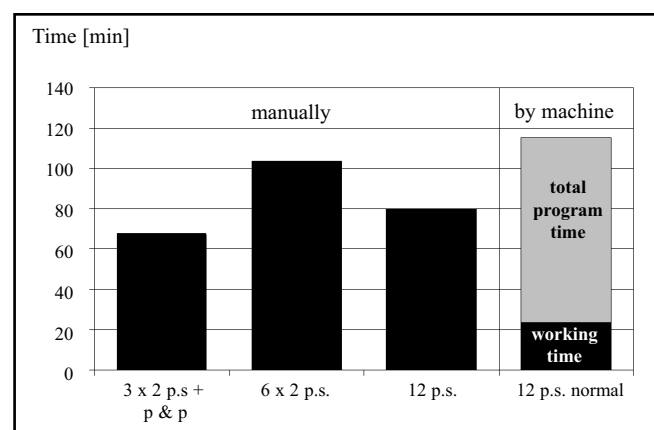
As regards time consumption, it can be said that all manual dishwashing processes consume a considerable portion of the daily time budget (Fig. 9). Although automatic dishwashing may take as long as manual dishwashing or even longer (depending on the model and the programme), the actual working time required for loading and unloading a dishwasher is much shorter.

This study can also be used to estimate European consumption averages for washing one place setting or cleaning one heavily soiled pot or pan (Table 6). The weighted average of the previous and the present study was calculated in order to produce the best possible consumption estimate. The real values vary from person to person, but the averages may be useful as an approximation to an assumed 'average behaviour'.

### 3.3 Comparison of washing-up liquids

As the three washing-up liquids used in our experiments were selected precisely for their differences in performance as determined in accordance with other test procedures, differences were expected to become evident in our measurements as well. Such evidence might show in different cleaning results or in higher or lower amounts of water (and energy) used to compensate for less efficient foaming or soil release properties. Moreover, as these differences had to be assumed to influence the consumption of washing-up liquid in our tests, each test person's individual water consumption and cleaning results from each of their three runs with two place settings were compared with their mean results. The deviations were afterwards sorted according to the type of washing-up liquid used.

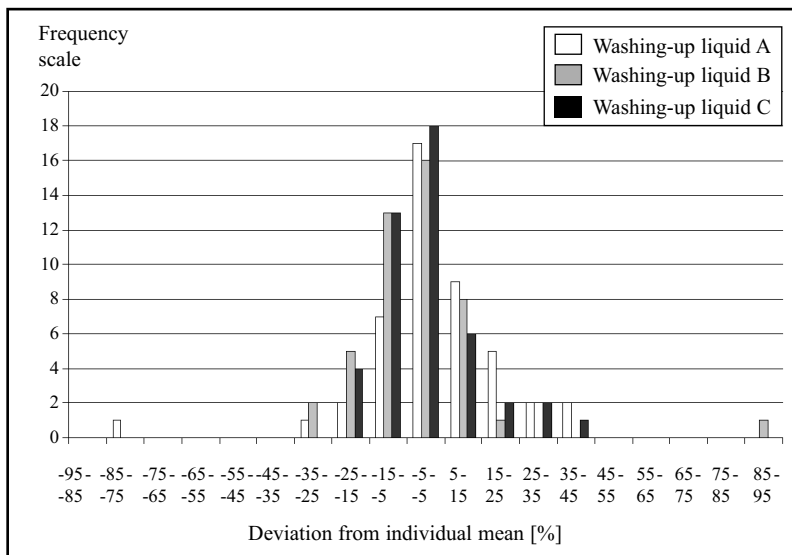
Figure 9: Comparison of time used for a full dishwasher load washed manually or by machine



Source: Own representation

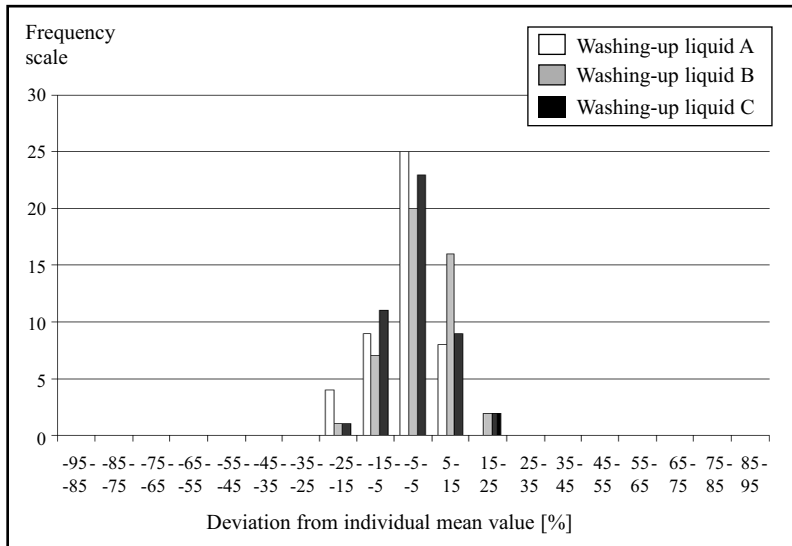
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Figure 10: Distribution of amount of water used from the mean values of each individual test person in % for different washing-up liquids



Source: Own representation

Figure 11: Distribution of cleaning index from the mean values of each individual test person in percent for different washing-up liquids used



Source: Own representation

Surprisingly, the analysis did not reveal any significant difference between the three products in terms of water consumption (Fig. 10) and cleaning performance (Fig. 11), the averaged differences being below 3 % and smaller than the standard deviation of each distribution. It was only with regard to the amount of washing-up liquid used that a difference became evident; on average, the consumption of product C was about 20 % lower than the individual test persons' average consumption, whereas the consumption of products A and B was about 10 % higher (Fig. 12). These results

confirm previous tests (Schmitz-Günther 2003), showing a higher efficiency in terms of dishes cleaned per g of washing-up liquid for product C in comparison with products A and B.

This analysis also revealed a very high degree of consistency in consumer behaviour with regard to dishwashing. Most volunteers used almost the same amounts of time and resources (except washing-up liquid) each time they washed their assortments of dishes and achieved an almost identical level of performance. There seems to be little spontaneity or accident involved in how most people wash their dishes. But the individual differences between people are very great.

#### 4 Conclusion

This study shows that washing smaller amounts of dishes results not in lower but in slightly higher amounts of resources being used in comparison with washing a larger number of items in a row. It also shows the great influence of heavily soiled pots and pans on total consumption values. On the basis of this study it is possible to estimate average specific consumption values for cleaning one place setting and one pot or pan. Such estimates can be argued to be the best available average data for Europe, but individual practice varies considerably. It has also been shown that the dishwashing behaviour of individuals is surprisingly constant and hardly a matter of accident. There seems to be for most people a personal target value of cleanliness to be achieved and the amount of washing-up liquid is adjusted as the only measure to reach this target.

As regards the normal household practice of washing small amounts of dishes and heavily soiled articles, our comparison confirms the advantages of automatic over manual dishwashing when comparing the average behaviour in manual washing with a fully loaded average dishwasher. These advantages can be identified

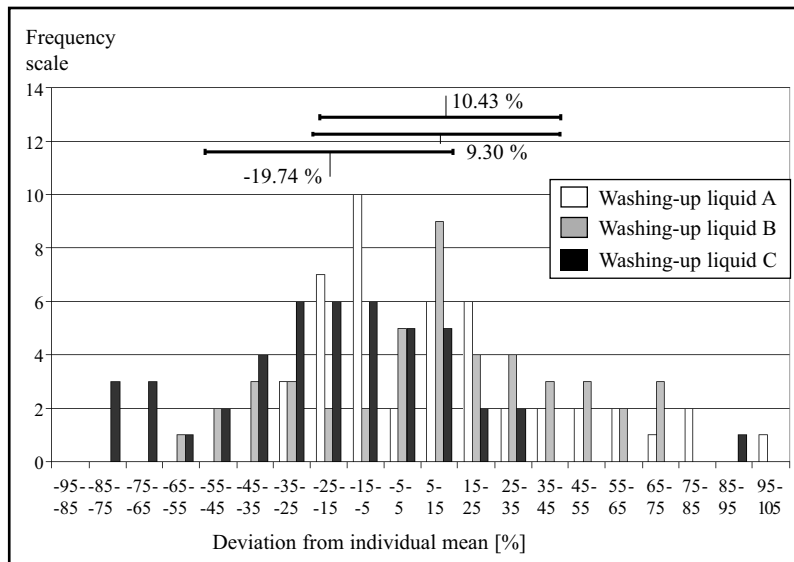
as lower consumption of water and energy and especially as better cleaning results and significantly lower amounts of manual working time needed.

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Figure 12: Distribution of amount of washing-up liquid used from the mean values of each individual test person in % for different washing-up liquids used. Also indicated is the average consumption and standard deviation for each washing-up liquid



Source: Own representation

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**Prof. Dr. Rainer Stamminger,**  
**Britta Rummler,**  
**Anja Elschenbroich,**  
**Dr. Gereon Broil**

University of Bonn  
Institut für Landtechnik  
Household and Appliance Technology Section  
Nussallee 5  
D-53115 Bonn  
Fon +49-(0)228-73-3117  
Fax +49-(0)228-73-2596  
[stamminger@uni-bonn.de](mailto:stamminger@uni-bonn.de)

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