Comparative analysis of global consumer behaviour in the context of different manual dishwashing methods

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Keywords
Consumer behaviour, resource consumption, manual washing up, automatic dishwashing, household appliances, household technology.

Abstract
This laboratory study presents an overview of the global manual dishwashing behaviour. The focus of the investigation was to analyse individual attitudes towards manual dishwashing and to determine the amount of water and energy used, as well as the cleaning performance achieved. Additionally, manual dishwashing was compared with automatic dishwashers. Two hundred eighty-nine participants from 29 countries took part in this investigation. Each consumer had to wash up a complete soiled dishwasher load consisting of 12 place settings based on both international and local performance test standards for automatic dishwashers. Country-specific aspects such as tableware, food residues or washing up equipment were considered. In order to analyse individual consumer’s behaviour, each participant was recorded on video and had to fill out a questionnaire. The resource consumption for washing up dishes was measured during the tests. At the end of each trial, the cleaning result of the washed up tableware was assessed. To compare manual with automatic dishwashing, country-specific dishwasher models were tested in parallel with three different programmes with the same soiled dish samples. The study provides comprehensive data about the average resource consumption for manual dishwashing for a specific load for each country. The average water consumption per country reached 34.7 l up to 160.1 l, and individual values ranged from 18.3 l to 472.8 l. The lowest used average heat quantity accounted for 0.9 kWh per country, while the highest amount was five times higher. The cleaning results did not differ much between the countries: the average test results were between 2.2 and 2.8 on a scale between 0 and 5. The automatic dishwasher tests showed differences between both the machines and the programmes. All machines achieved lower water consumption values than the average consumers with about 9.6 l to 26.7 l of water on average. The energy consumption ranged from 0.5 kWh on average up to 2.0 kWh. The cleaning results of the dishwasher tests varied highly ranging from 1.1 in a quick programme to 4.4 in an intensive programme. The study comes to the conclusion that automatic dishwashing is more superior as compared with manual dishwashing in terms of performance and resource consumption under the tested conditions. Furthermore, it points out that washing up dishes under running tap water is the most water-consuming manual dishwashing method of all investigated ones. A high lack of knowledge about the benefits of automatic dishwashing compared with manual dishwashing can still be identified among consumers.

Introduction
Sustainability and sustainable development are both terms that have been given various meanings by politicians, socialists, economists and ecologists in the past decades. Early discussions about the concept of sustainable development were phrased back in the 1960s during a UNESCO Conference (International Institute for Sustainable Development, 2002). Over the years, publications, research findings and global conferences made up the concept of sustainability as the focus of their interest. An outcome of all these discussions was a definition of the term sustainable development, summarized 1987 in ‘Our Common Future’, better known as the Brundtland Report (United Nations, 1987). Two main definitions of sustainability are named within this document:
1 ‘Sustainable development seeks to meet the needs and aspirations of the present without compromising the ability to meet those of the future’ (United Nations, 1987, p. 51).
2 ‘In essence, sustainable development is a process of change in which the exploitation of resources, the direction of investments, the orientation of technological development, and institutional
change are all in harmony and enhance both current and future potential to meet human needs and aspirations’ (United Nations, 1987, p. 57).

But in the background of the increasing effect of climate change and global warming, all political efforts that have been made until today do not seem to be enough. At present, the decrease of non-renewable resources makes it necessary to rethink about energy and water demand behaviour not only in the domestic sector. Both the world population and also the demand for resources are continually growing (United Nations, 2005).

Already today, one of the largest energy users in the European Union is the domestic household sector due to its increasing demand for heating and appliances (European Environment Agency, 2005). Future prospects expect, that especially in the developed countries, consumers will be even more dependent on appliances due to lifestyle changes and the increasing desire for technology and comfort. Furthermore, a trend towards smaller household sizes can be identified. Simultaneously, the number of single households is increasing as well (European Environment Agency, 2005; European Commission, 2008). Future prospects indicate for Europe that the household energy demand will rise by 12% until 2030 (European Commission, 2008). Due to these developments, the household appliance industry – especially for those of white goods – has made a step forward to encourage consumers to act in a more sustainable way by implementing energy labels. Less efficient appliances disappeared from the market, because consumers demanded machines with higher efficiency classes (Presutto et al., 2007).

When looking at the market saturation of household appliances on a global base, inhomogeneous distribution can be identified even for the higher developed countries. Taking dishwashing as an example, automatic dishwashers show an increasing market share in Germany and the United States during the last decades (US Energy Information Administration, 2001; Zentralverband Elektrotechnik- und Elektronikindustrie e.V., 2011), because the usage of this household appliance is common in both countries for decades. But there are still countries with a low market saturation of automatic dishwashers, where these appliances almost have a status of luxury goods (Grady, 2004). Different lifestyles, traditions and needs, but also high purchasing costs, can be assumed as reasons for this market development. It indicates that in these countries, a lot of different household tasks are still done without the help of certain appliances, for example, dishwashing. But while household appliances have to fulfill specific standards for energy and performance tests before being launched in the market, there are only limited data available about how many resources are used for many home tasks that are still done by hand. Low knowledge about new technologies and a low awareness about the resource consumption of daily routine procedures among consumers are still present. Therefore, additional research is needed to disclose this gap, for example, by providing well-founded data that can be used as a basis for consumer education.

On the topic of dishwashing, several investigations tried to disclose both resource consumptions and consumer habits on a European base (Stamminger et al., 2007; Berkholz et al., 2010; Richter, 2010; Vivian et al., 2011). Stamminger et al. (2007) gave a first detailed analysis of both manual dishwashing habits and data measurements about the energy and water consumption as well as the cleanliness of the washed up tableware. Because the European investigation was only based on a limited number of participants, Berkholz et al. (2010) replicated the study by choosing a larger and fully representative sample of UK participants. In addition, each study compared the hand wash results with those of an automatic dishwasher tested under the same conditions. Both studies were conducted in a laboratory under consumer relevant test conditions. In contrast to that, Richter (2010) investigated 200 households in four European countries to identify the washing up behaviour under real-life conditions. The analyses of Vivian et al. (2011) focused on the energy and the associated carbon dioxide equivalent emission from both washing up dishes by hand and using an automatic dishwasher. Additionally, the consumer behaviour was also taken into account in the assessment. All studies came to the conclusion that on average, a dishwasher needs considerably less water and energy and reaches on average better cleaning results when used efficiently compared with hand wash. Because these studies were only limited to some European countries, the need of future investigations was given to include also habits and attitudes of consumers in non-European countries.

Research question
Published research have already investigated washing up habits both under laboratory and real-life conditions. But their focus was limited to consumers living in Europe, where living conditions do not differ that much between countries. In order to get a deeper insight into washing up habits and resource consumption for manual dishwashing outside the European Union, the main aim of the present investigation should be to broaden the existing European studies by including also non-European countries into the focus of research. Thereby, a better understanding of worldwide manual dishwashing practices and consumer insights are given which could be used to develop recommendations for best practices in the future. Participants of several representative states from all continents were chosen to take part in the study. Tests were performed in Germany and abroad. The analysis of consumer behaviour should be researched, on the one hand, by measuring energy and water consumption data as well as the cleaning result. On the other hand, washing up techniques and habits should be identified within a non-participant observation and a questionnaire. Based on this, it should be researched if similar results like in the investigation of Stamminger et al. (2007) and Berkholz et al. (2010) could be found. Furthermore, it should be discovered if the consumers really behave in the same way as they answered in the questionnaire.

To compare manual with automatic dishwashing, dishwasher models that are characteristic of each participating country should be tested in parallel with the same dish samples as for the specific test countries.

Materials and methods
Consumer study
Overall, 289 consumers took part in this investigation. The majority of the tests were conducted in the laboratories of Bonn University. Furthermore, additional consumer tests were also performed abroad in three different countries. All participants
were citizens from one of the seven investigated regions that were selected in order to represent all continents (Table 1).

Consumers had to match specific criteria in order to take part in this research: none of them were permitted to have lived more than 3 years in Germany. This was to avoid the participants adopting German habits. Additionally, participants must have experience in manual dishwashing and had to be older than 18 years.

For the consumer tests performed in Germany, the recruitment of the panel was done in two cities named Bonn and Cologne. Trialists were recruited through notes posted on the campus in both German cities, but also using web-based social networks and foreign country organizations. The same recruitment method was also used for the tests done in China. For the investigations in South Africa and the United States, participants were recruited by telephone from user panels by simple random sampling. The user panels were generally used for consumer research at Reckitt Benckiser Ltd. and BSH Home Appliances Ltd.

The test setup and preparation for the consumer study performed in Germany and abroad were identical. The conduction of all tests was done by a scientific research group of Bonn University. Tests were performed under uniform conditions similar to the international test standard IEC 60436:2004+A1:2009 (E) – Electric dishwashers for household use – methods for measuring the performance (International Electrotechnical Commission, 2009).

In total, 12 place settings were soiled with specific food for each consumer test. Six place settings were prepared similar to the IEC

### Table 1 Consumer panel: country of origin and no. of consumers per test country

<table>
<thead>
<tr>
<th>Region</th>
<th>Abbr.</th>
<th>Nationality/ethnicity</th>
<th>No. of participants</th>
<th>Among these tested abroad</th>
<th>Used dishwasher test standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>New Zealand</td>
<td></td>
<td>New Zealand</td>
<td>3</td>
<td>–</td>
<td></td>
</tr>
<tr>
<td></td>
<td>RU</td>
<td>Belorussian</td>
<td>1</td>
<td>–</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Georgian</td>
<td>4</td>
<td>–</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Russian</td>
<td>10</td>
<td>–</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ukrainian</td>
<td>4</td>
<td>–</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Uzbekistani</td>
<td>1</td>
<td>–</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Brazilian</td>
<td>5</td>
<td>–</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Colombian</td>
<td>9</td>
<td>–</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mexican</td>
<td>4</td>
<td>–</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Peruvian</td>
<td>1</td>
<td>–</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Iranian</td>
<td>4</td>
<td>–</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Jordanian</td>
<td>3</td>
<td>–</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Omani</td>
<td>1</td>
<td>–</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Pakistani</td>
<td>2</td>
<td>–</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Palestine</td>
<td>4</td>
<td>–</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Syrian</td>
<td>2</td>
<td>–</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Yemeni</td>
<td>2</td>
<td>–</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mosotho</td>
<td>1</td>
<td>–</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>South African</td>
<td>17</td>
<td>17</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Asian</td>
<td>7</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Black/African American</td>
<td>4</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Hispanic/Latino</td>
<td>4</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Two or more races</td>
<td>4</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>White</td>
<td>63</td>
<td>45</td>
<td></td>
</tr>
</tbody>
</table>
The following data were measured with a calibrated data logging system that recorded all incoming data every second:

- Houston, TX, USA (US): 0.7–1.5 mmol/l.
- Denver, CO, USA (US): 0.7–1.5 mmol/l;
- Montvale, NJ, USA (US): 1.5–2.5 mmol/l;
- Beijing, China (CN): 3.7 mmol/l;
- Johannesburg, South Africa (ZA): 1.4 mmol/l.

Local water hardness levels were measured. The local town water was taken. The water hardness was measured using calibrated in-line flow meters.

The cold and hot water consumptions were measured using calibrated in-line flow meters.

The cold and hot water temperatures were taken using thermocouples. The energy and the heat quantity used to heat up the water were calculated using the following equation:

\[ Q_{\text{hot}} = (V_{\text{hot}} \times c \times (T_{\text{hot}} - T_{\text{cold}}) + V_{\text{hot}} \times c \times (T_{\text{cold}} - 15^\circ \text{C}))/3600 \]  

with:

- \( Q_{\text{hot}} \) = heat quantity of warm water in kWh;
- \( V_{\text{hot}} \) = volume of warm water in l;
- \( T_{\text{hot}} \) = temperature of warm water in °C;
- \( T_{\text{cold}} \) = temperature of cold water in °C; and
- \( c \) = specific heat capacity of water: 4.19 kJ/kgK.

The calculated heat quantity was corrected according to the temperature of the cold water so that the adjusted value was equivalent to the amount of heat quantity that would have been used if the incoming cold water had been a temperature of 15°C.

All participants were left alone during the experiment in order to keep factors that might have an influencing impact on the behaviour as small as possible. Each trialist was recorded on video while washing up. The videos were used to analyse the individual habits. Therefore, all dishwashing steps of each consumer were counted. One dishwashing step is thereby defined as the manual washing up process of a composition of equal dishes, e.g. glasses, cups, saucers, etc. In a next step, it was analysed how many of all the dishwashing steps were done (1) under running tap water; (2) in a water-filled sink; or (3) by combining both methods. At the end of each test, the cleanliness of the washed up tableware was assessed visually according to EN 50242:2008 (Europäisches Komitee für Elektrotechnische Normung, 2008) (Table 3).

### Dishwasher study

In parallel to the consumer study, dishwasher tests were also performed in the laboratories of Bonn University. In total, six country-specific dishwasher models were tested (Table 4) for different countries, including Germany, Hungary, Russia and the countries belonging to the Middle East (ME) and Southern Africa. Each machine was tested 10 times in accordance with the standard of the country the machine was designed for. The different dishes were counted. One dishwashing step is thereby defined as the manual washing up process of a composition of equal dishes, e.g. glasses, cups, saucers, etc. In a next step, it was analysed how many of all the dishwashing steps were done (1) under running tap water; (2) in a water-filled sink; or (3) by combining both methods. At the end of each test, the cleanliness of the washed up tableware was assessed visually according to EN 50242:2008 (Europäisches Komitee für Elektrotechnische Normung, 2008) (Table 3).

### Tables

#### Table 2: Test standards and soiling agents

<table>
<thead>
<tr>
<th>Test standard</th>
<th>Soiling agents</th>
</tr>
</thead>
<tbody>
<tr>
<td>AS/NZS 2007.1</td>
<td>Black tea, egg yolk, infant cereal, margarine, spinach, tomato juice</td>
</tr>
<tr>
<td>JEMA HD-084</td>
<td>Curry-rice, cutlet with sauce, egg sunny-side up, green tea, milk, miso soup, rice, tomato juice</td>
</tr>
<tr>
<td>MKE’s notification 2008–99</td>
<td>Cayenne pepper, coffee, egg yolk, kimchi, margarine, milk</td>
</tr>
<tr>
<td>ANSI/AHAM 2005-DW-1</td>
<td>Coffee, coffee ground, egg yolk, mashed potatoes, minced meat, porridge, preserves, sweet corn, tomato juice</td>
</tr>
</tbody>
</table>

#### Table 3: Evaluation of the cleaning performance according to EN 50242:2008 (Europäisches Komitee für Elektrotechnische Normung, 2008)

<table>
<thead>
<tr>
<th>Score</th>
<th>Number of small dot-shaped particles (n)</th>
<th>Total soiled area in mm² (A)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>( n = 0 )</td>
<td>( A = 0 )</td>
</tr>
<tr>
<td>4</td>
<td>( 0 &lt; n \leq 4 )</td>
<td>( 0 &lt; A \leq 4 )</td>
</tr>
<tr>
<td>3</td>
<td>( 4 &lt; n \leq 10 )</td>
<td>( 0 &lt; A \leq 4 )</td>
</tr>
<tr>
<td>2</td>
<td>( 10 &lt; n )</td>
<td>( 4 &lt; A \leq 50 )</td>
</tr>
<tr>
<td>1</td>
<td>Not applicable</td>
<td>( 50 &lt; A \leq 200 )</td>
</tr>
<tr>
<td>0</td>
<td>Not applicable</td>
<td>( 200 &lt; A )</td>
</tr>
</tbody>
</table>

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countries. The test preparation of the tableware was equivalent to those done for the manual washing-up experiment. In order to reflect different consumer habits when using a dishwasher, three different dishwasher programmes were tested in each machine: a quick, normal and intensive cycle. The used automatic dishwashing detergent was the Reference Detergent Type B (Wfk, Testgewebe, Krefeld, Germany), and the rinse agent was Formula III (Wfk) according to IEC 60436:2004 + A1:2009 (International Electrotechnical Commission, 2009). No special salt was added to the machines. Each machine was run with local town water at a water hardness level of 1.1 mmol/l on average.

The following data were recorded every second using a calibrated data logging system:

- The total water consumption $V_{\text{inl}}$ was measured using calibrated in-line flow meters.
- The temperature $T_{\text{inl}}$ of the incoming water was taken using thermocouples.
- The energy consumption $E_{\text{mea}}$ was measured. Equivalent to the consumer study, the used energy was corrected up to a cold water temperature of 15°C using the following equations according to IEC 60436:2004 + A1:2009 (International Electrotechnical Commission, 2009):

$$E_{\text{corr}} = E_{\text{mea}} \times \frac{V_{\text{inl}} \times c \times (T_{\text{inl}} - 15°C)}{3600}$$  
(2)

with:
- $E_{\text{corr}}$ = corrected energy consumption in kWh;
- $V_{\text{inl}}$ = total water consumption in l;
- $T_{\text{inl}}$ = temperature of the incoming water in °C; and
- $c$ = specific heat capacity of water: 4.19 kJ/kgK.

$$E_{\text{total}} = E_{\text{mea}} + E_{\text{corr}}$$  
(3)

with:
- $E_{\text{total}}$ = total energy consumption in kWh; and
- $E_{\text{mea}}$ = measured energy consumption in kWh.

At the end of each programme, the cleaning performance was assessed visually according to EN 50242:2008 (Europäisches Komitee für Elektrotechnische Normung, 2008).

Results and discussion

Characteristics of the consumer panel

A consumer sample of, in total, 289 people took part in the investigation. Participants were all inhabitants of 29 countries which were allocated to seven worldwide regions (Table 1). Consumers were between 18 to over 64 years old. The majority of participants were younger than 35 years (64%). More than two-thirds of the participants were female. Two to three individuals per household was the household size that occurred most frequently (Table 5).

Overview on the resource consumption for manual and automatic dishwashing

Figures 1–3 show the median results of the water consumption, the corrected energy and corrected heat quantity consumption and the
cleaning results for both the user trial and the automatic dishwasher tests.

The median values of the consumer trial indicate high differences between the countries (Fig. 1). The median values range from 34.7 l (AU/NZ) up to 160.1 l (RU). But also within one country, the taken data show a high variation. Countries within a small difference between the 75th and the 25th percentile – that means countries where the majority of consumers wash up in a more uniform way – can be identified (AU/NZ: D 19.6 l, ZA: D 28.8 l, DE: D 29.9 l). In contrast to that, 50% of the participants from Russia needed between 86.4 l and 221.4 l of water to wash up a similar dish amount. Extreme values were measured as well. The lowest water consumption was at 18.3 l (AU/NZ), while the highest was up to 26 times higher (US: 472.8 l).

The water consumption results in the dishwasher tests showed lower values for all machines in all programmes compared with the manual washing up tests. The lowest water consumption results for all machines were measured in the quick cycle. The measurements range from 9.6 l [Latin America (LATAM)] up to 12.7 l (US). In contrast to that, in the intensive programme, between 12.8 l (LATAM) and 26.7 l (US) were used.

In the consumer test, a significant relationship between the water consumption and the corrected heat quantity can be identified \( r_s = 0.76 \ P \text{ (one-tailed)} < 0.01 \). Therefore, a similar distribution of the corrected heat quantity data compared with the water consumption can be observed (Fig. 2). The median values range from 0.9 kWh (ZA) to 4.6 kWh (RU). The country with the largest range of the middle 50% is again RU with a difference of 3.8 kWh. The lowest range between the 25th and the 75th percentile was measured for AU/NZ (D 0.5 kWh). Extreme values were calculated for the corrected heat quantity as well. Some participants did not use any hot water at all for washing up (JP, CN, ZA, US), so that no heat quantity could be calculated. Those consumers stated that they did not use any hot water for washing up dishes at home either. Named reasons were either that those consumers do not have any hot water supply at their kitchen sink at home or that they live in regions with a very warm climate, which makes it unnecessary to heat up the water. In contrast to the lowest calculations, the highest value was almost 15 kWh (US).

The average dishwasher results of the corrected energy consumption are in general lower than those of the consumers. In the quick cycle, measurements range from 0.5 kWh (JP) to 0.9 kWh (US), and in the intensive cycle from 1.1 kWh (JP) to 2.0 kWh (US). However, in the consumer tests, some countries...
still achieved on average lower values (AU/NZ, CN, ZA) due to the fact that they used in total less warm water. Reasons for that were either to save water in general (AU/NZ) or because – as mentioned above – some participants were not accustomed to using a lot of warm water or indeed any warm water at all for washing up dishes (CN/ZA). The differences of the resource consumption values both between the countries and within one country indicate that different washing up methods were used that effect those high deviations. Similar results were also observed in the investigations of Stamminger et al. (2007) and Berkholz et al. (2010).

Having a closer look at the cleaning results (Fig. 3) to compare the middle 50% within the countries, again large differences can be assessed. Countries with a relatively low range between the 25th and 75th percentile can be defined (LATAM & JP: Δ 0.8) as well as countries with a larger range (CN: Δ 1.7). Based on this, it can be assumed that consumers in those countries seem to have a more differentiated picture of cleanliness than others. Possibly, the deviations in the cleaning results are linked to a higher variety of washing up techniques within one country. On the opposite, the median values of all countries lay quite close together ranging only from 2.2 (LATAM) to 3.0 (HU). This could be seen as an indicator for a similar meaning of cleanliness among all participants. On average, participants washed up until the favoured cleaning level was achieved.

The cleaning results of the dishwasher tests show differences in the performance of the six tested models. The lowest performance of all machines was achieved by the Japanese dishwasher in all programmes. Even the Japanese consumer panel achieved better average cleaning results than the machine did. Overall, the performance in all quick cycles is lower compared with the average consumer results. In contrast to that, the cleaning scores in the normal and intensive cycles are higher or equal (US) to the average results of the consumers. The best performing models are the EU and LATAM dishwashers. Their results range between 2.1 and 2.2 in the quick programme up to 4.2 (EU) and 4.4 (LATAM) in the intensive cycle.
The attitude of consumers towards dishwashing

Thirty-three percent of all participants stated that they had a dishwasher at home. The main purchase reason for those consumers is the time-saving aspect when using a dishwasher (69%). Forty-five percent responded that they regularly have so many dirty dishes at home that the use of a dishwasher is necessary. The third important aspect (36%) is that the cleaning result of dishes washed in a dishwasher is better compared with hand washed dishes. Less than one-third of the dishwasher owners answered that they use the machine in order to save water and energy. These findings can also be supported by the studies of Stamminger et al. (2007) and Berkholz et al. (2010). Also in these investigations, resource savings were found not to be on top of consumers’ minds when purchasing a dishwasher.

In a further question, people had to estimate which one of the two dishwashing methods delivers a better cleaning result (Fig. 4). Thirty-nine percent of all participants said that manual dishwashing reaches a better performance while only 25% answered that an automatic dishwasher cleans better. Only the majority of Hungarian (HU: 50%) and US Americans (US: 49%) thought that using a dishwasher results in a higher performance. The common usage of automatic dishwasher among US consumers could be seen as one possible reason why US Americans are persuaded of the performance of a dishwasher. Instead, among the Asian countries (KR, JP) where dishwasher usage is not very common, a clearly low belief in dishwasher cleaning results can be identified. This is also true for the developing countries in LATAM and the ME.

Forty-three percent of dishwasher owners replied that a dishwasher cleans the dishes better than manual dishwashing. Nevertheless, 37% still think that manual dishwashing results in a higher cleanliness. As this is not supported by the dishwasher test results within this study (Fig. 3), the continuously wrong usage of the appliance and the cleaning detergent might be a reason for this opinion, e.g. incorrect programme choice, improper loading conditions, damp detergent, etc.

In total, 37% of all participants replied that manual dishwashing saves more energy and water than automatic dishwashing. In contrast to that, about 33% were of the opinion that automatic dishwashing is more economic friendly (Fig. 4). When only looking at the group of people who have a dishwasher at home (33%), over 50% replied that automatic dishwashing saves water and energy.
compared with manual dishwashing. But still, approximately one-third believe that manual dishwashing is more economic friendly.

**Consumers’ manual washing up behaviour and its impact on water consumption**

On the basis of both the questionnaire and the video analysis, three different washing up methods could be identified: washing up (1) under running tap water; (2) in a water-filled sink; and (3) in a combined way of both under running tap water and in a filled sink (Figs 5 and 6).

When looking at the consumer panel in total, the running tap water method can be named as the predominant method for washing up. Forty-five percent of all the trialists who stated that they wash the dishes manually \((n = 284)\) do the dishes this way. Similar percentages in the groups of dishwasher owners and non-owners were evaluated to wash up under running tap water (dishwasher owners \(= 43\%\), dishwasher non-owners \(= 46\%\)). This way of washing up remains also as the main dishwashing method in almost all investigated countries. Exceptions are consumers from Australia/New Zealand (AU/NZ) and Southern Africa (ZA) where the majority of people replied to do the dishes in a sink filled with water.

The video analysis shows that over 50% of the consumers in five of the test countries (RU, LATAM, KR, JP, ME) do more than 70% of all dishwashing steps under running tap water (Fig. 7). Countries like Hungary (HU), China (CN) and the United States (US) tend to combine both methods. The majority of people from these three countries do between 30 and 70% of all dishwashing steps under running tap water. Countries like Germany (DE), Southern Africa (ZA) and Australia/New Zealand (AU/NZ) are more in favour of washing up in a water-filled sink because more than 50% of the consumers washed up less than 30% of all dishwashing steps under running tap water. This analysis proves that participants of countries that stated doing the dishes previously under running tap water finally washed up the dishes with this method in the test. The same findings could be noticed for consumers washing up in a filled sink or combining both methods.

A statistical comparison was done in order to analyse whether the washing up method is related to the water consumption. Because the analysed variables violate parametric assumptions, the Spearman’s correlation coefficient \(r_S\) was calculated. A bivariate correlation analysis was done using the statistical programme PASW Statistics 18 (IBM Corporation, Armonk, NY, USA) for the variables ‘total water consumption’ and the ‘frequency of dishwashing steps done under running tap water’. There is a significant positive relationship between both variables \([r_S = 0.71, P\) (one-tailed) \(< 0.01]\). An increase of the number of dishwashing steps performed under running tap water relates to an increase in the total water consumption. A significant correlation between the variables ‘total water consumption’ and the ‘frequency of dishwashing steps done in a filled sink’ cannot be confirmed, which means an increasing number of steps done in a filled sink does not result in higher water consumption. This is due to the fact that several dishwashing steps can be done with just one sink filling without any water changes in between.
Finally, a statistical analysis was done to clarify if there is a significant difference in the water consumption of consumers who washed up predominantly under running tap water compared with those who mainly washed up in a water-filled sink. That means people who washed up more than 70% of all dishwashing steps under running tap water in the test were compared with consumers who washed up less than 30% of all dishwashing steps under running tap water. Because all variables violate again parametric assumptions, the Mann–Whitney U-test was used. The total water consumption of consumers who washed up more than 70% of all washing up steps under running tap water (median = 148.19 l) differed significantly from consumers who washed up less than 30% of all steps in a filled sink [median = 75.57 l, U = 2374.50, z = -5.36, P (two-tailed) < 0.001, r = -0.39].

Conclusion and outlook

Compared with existing investigations, the presented study provides a deeper insight into worldwide washing up habits by including both European and non-European countries into the focus of research. New insights are found about country-related washing up practices that show a connection between the water use for manual dishwashing and the impact on water consumption. Participants from all continents took part. In addition, automatic dishwashers were included to compare the resource consumption and cleaning performance of both manual and automatic dishwashing within a laboratory test.

In compliance with previous research findings (Stamminger et al., 2007; Berkholz et al., 2010), this consumer study provides also a wide range of measured water and energy consumption data as well as cleaning results, which demonstrated that dishwashing habits vary dramatically between countries and regions. In addition, the study points out that under the tested conditions, almost all dishwasher models achieve a better cleaning result and use less water and energy compared with the consumer tests. This is especially valid for the dishwasher results measured in the normal programme.

Nevertheless, it should be pointed out that the presented findings are based on specific test conditions. The approach of this research is limited because of its simulated test setup. Real-life conditions in the respective countries may differ from the results summarized in this study. This is due to the fact that factors like cultural differences in cooking practices, household sizes and living conditions, for example, in urban or rural areas could not be taken into account but may have a deep impact on household practices. Therefore, future investigations need to be conducted which need to include social and psychological factors too. In addition, more detailed analysis needs to be done with a representative consumer sample for each of the investigated countries in order to verify statistically the presented results.

The video analysis clearly shows that consumers apply different water usage methods for manual dishwashing. In the correlation analysis between the water consumption measures and the used manual dishwashing method, the findings indicate that washing up
under running tap water especially has a high impact on the water consumption compared with washing up in a filled sink.

Comparisons between results of both the questionnaire and the videos demonstrate that the majority of the consumers are aware of their dishwashing method but not about the consequences of their behaviour on the resource consumption. The survey showed that a high percentage of consumers are still of the opinion that manual dishwashing uses less resources than automatic dishwashing. Furthermore, the majority of people believe that a dishwasher achieves poorer cleaning results than manual dishwashing. Reasons for these findings can be found in the fact that a high percentage of participants (67%) did not have a dishwasher at home and therefore could not estimate the benefits that automatic dishwashers have against manual dishwashing.

Washing up dishes is not a common topic in consumers’ minds. It is a mundane and frequent household routine that is not reflected. Its aim is to achieve clean dishes in the first place. The environmental impact that manual dishwashing has compared with automatic dishwashing is less important to people proven by this survey.

For people to be more aware about the importance of a sustainable usage of resources, deeper discussions and communication are needed about both the consequences of a non-reflected water and energy use. But also the potential savings consumers can achieve when using a dishwasher instead of washing up by hand needs to be more highlighted. The first step has already been done by the appliances industry and related businesses by developing both more efficient machines and campaigns that promote the ecological benefits of automatic dishwashing. Nevertheless, strong promotions do not seem to be enough to overcome the barrier of consumer behaviour. Consumer communication needs to be both more focused on the target audience and more culturally sensitive. More realistic approaches are needed. Slogans and metaphors do not seem to effect big changes in peoples’ mindsets. But showing simple and more engaging solutions that are easy to understand and realize into daily life habits and routines might achieve a higher impact. Therefore, future investigations should lay their focus on developing country-specific communication and education tools. For this purpose, the findings of this research provide the basis of a better understanding about consumer behaviour.

Figure 6 What is your preferred way of doing the dishes by hand? (AU/NZ: Australia/New Zealand, manual dishwashing; JP: Japan, manual dishwashing; KR: Korea, manual dishwashing; CN: China, manual dishwashing; ME: Middle East, manual dishwashing; ZA: Southern Africa, manual dishwashing; DE: Germany, manual dishwashing; RU: Russia, manual dishwashing; LATAM: Latin America, manual dishwashing; US: United States, manual dishwashing).
Nevertheless, there are still countries with a low market saturation of automatic dishwashers due to a low income, cultural boundaries and harsh living conditions, especially in rural areas with insufficient infrastructure. The usage of an electric appliance in these countries is not yet a realistic target. However, a contribution to a sustainable behaviour on dishwashing can be achieved. Consumers need to be better educated about best hand dishwashing practices, for example, by demonstrating the difference in water consumption when washing up under the running tap instead of in a filled sink (Fuss et al., 2001). Influencing adults who are already set in their behaviour can be realized more efficiently by laying the focus on children’s education. Research findings demonstrated in several studies that children are more open to new insights and in experiencing new circumstances compared with adults. Therefore, they can be seen as a ‘key audience for environmental messages’ (Ballantyne et al., 1998, p. 285).

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**References**


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![Figure 7 Percentages of consumers per country according to the percentages of dishwashing steps done under running tap water (AU/NZ: Australia/New Zealand, manual dishwashing; JP: Japan, manual dishwashing; KR: Korea, manual dishwashing; CN: China, manual dishwashing; ME: Middle East, manual dishwashing; ZA: Southern Africa, manual dishwashing; DE: Germany, manual dishwashing; HU: Hungary, manual dishwashing; RU: Russia, manual dishwashing; LATAM: Latin America, manual dishwashing; US: United States, manual dishwashing).](image-url)
P. Berkholz et al.

Analysis of global manual dishwashing methods


