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ORIGINAL ARTICLE

Global consumer study to identify the potential of water-saving in dishwashing

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Abstract Water and energy dissipation is a remaining problem in the world and dishwashing is contributing to this. The correct cleaning technique can help to save resources, but needs to be promoted, as consumers tend to clean without thinking a lot about their technique. A global consumer survey was carried out and helped to identify common mistakes in dishwashing, which show the potential for improvement: Automatic dishwashers are partly rejected because of misunderstanding the big advantages. Furthermore, running cold tap-water is used frequently, and dishes are cleaned individually in manual dishwashing. Although the participants see themselves as interested in environmental topics, they are not aware of their personal potential to save resources during daily household work. This shows that the interest and the knowledge about sustainable dishwashing methods and the efficiency of automatic dishwashers needs to be increased.

Keywords Household work · Energy efficiency · Sustainable household behavior · Sustainability · Water consumption in dishwashing · Dishwasher

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Introduction

Influencing consumer behavior is often considered the key to energy saving and a lower greenhouse gas emission. The energy consumption in households caused 25% of the greenhouse gases in 2010 (IPPC, 2014). This sector, with 17% per year, has achieved the highest energy efficiency improvement in the European Union between 2007 and 2015. This increase in efficiency is equalizing the growth in economic activity, which causes a higher demand for electricity usage (ODYSEE MURE 2015).

A high percentage of energy consumption in households is required for cleaning, mainly caused by the requirement of water heating (ODYSEE MURE 2015); therefore, using less water during household work would help to save energy significantly. The huge influence of the personal approach as a factor that decides about the water consumed during household work, here focusing on dishwashing, is undeniable: A comparison of the dishwashing behavior between 289 participants from nine countries showed that, under standardized conditions regarding the number of plates and amount of soiling, the individual water consumption ranged from 18.3 to 472.8 L per session (Berkholz et al. 2013).

Stamminger (2006) compared the resource consumption in manual and automatic dishwashing from different studies. This detailed analysis shows that the most efficient way to save water is by replacing manual dishwashing with automatic dishwashers. Water saving, little time and energy consumption, and very hygienic

cleaning results are advantages of an automatic dishwasher (Stamminger 2006). Moreover, the leading dishwasher manufacturers are constantly developing even more efficient appliances with new features, such as sterilizers or connections with smartphones (Euromonitor International 2014). However, the penetration of automatic dishwashers is below 5% of the households in Southeast Asia and Latin America, and under 10% in Africa, the Middle East, and Eastern Europe. In Australia, New Zealand, and Japan, where other white goods, such as refrigerators, washing-machines, and microwave ovens, reach penetrations above 80%, automatic dishwashers remain far behind with around 40% (Electrolux, 2014). While appliances such as washing-machines and automatic dishwashers are becoming more efficient, consumers are wasting water and energy by not using these appliances at all or using them incorrectly. A study of 4000 households in Germany identified highly different ways of using automatic dishwashers. It was shown that the use of the eco program, which saves the most water, was often combined with a manual pre-rinsing step which negatively equalized the resource savings. Furthermore, a detailed diary study showed that the energy consuming "Intensive Programme" is used by 13.7%, the "Automatic Programme" by 25.7%, and the "Eco Programme" by 22.4%. A simple change towards another program button of the appliance could help the consumer save a lot of energy and water (Bichler et al. 2015).

When not cleaning with an automatic dishwasher, the manual dishwashing technique moves into focus for resource saving. Studies on manual dishwashing have identified that the use of a filled sink for both cleaning and rinsing is the most efficient way to clean with little water without compromising on the hygiene (Fuß and Stamminger 2010). Problem is, that this practice is hardly applied in any household worldwide. Running tap-water use is common practice (Berkholz et al. 2013; Maitra et al. 2017; Stamminger et al. 2007).

However, when it comes to intervention of consumer behavior, it is no longer that simple. There are multiple intervention studies differing in target groups, costs, and effort. The effectiveness of consumer interventions on energy consumption behavior in 38 cases was reviewed by Abrahamse et al. (2005). For an effective intervention, good planning and effectiveness cannot be assessed in all their aspects without underlying physiological determinants. This makes influencing household behavior very complicated, as it is often performed unconsciously and is not reflected upon. A study of 40 people has shown that the participants do not adapt their resource consumption to the number of dishes or amount of soiling, but just clean as they have always done (Gilleßen et al. 2012). Next to classical intervention studies are also studies on the application of social practice theories in intervention studies on pro-environmental behavior. In this case, the focus is not on the individual person but on the collective, as this eliminates the problem of the limiting individual cognitive state and context settings (Hargreaves 2011).

Research question

The aim is to identify which behavioral mistakes lead mainly to the wastage of water and energy. The identification of common mistakes in dishwashing is an important step towards more sustainable household work.

A survey was set up in nine countries in different regions to get a global picture of dishwashing techniques.

Materials and methods

A consumer study was conducted as on online survey from December 2014 to January 2015. The market research agency Toluna Germany GmbH hosted the survey and contacted consumers of their panel in nine countries by fulfilling the ESOMAR[1] criteria (ESOMAR, 2011). Participation criteria were set at 70% female and 30% male, age from 18 to 65 years, and the requirement of household responsibility of all participants. The countries involved were Argentina (AR), Brazil (BR), China (CN), Germany (DE), India (IN), Indonesia (ID), Italy (IT), Russia (RU), and South Africa (ZA), with a planned number of 1000 participants each.

The number of 1000 was slightly reduced by the additional internal quality control—two questions on the same topic were asked and participants with inconsistent answers were eliminated from the survey. The total number of participants per country and the spread of Living Standard Measurement (LSM) and Environmental Awareness (EnAw) classes in the countries are shown in Table 1. Two questions were asked to allow a

[1] European Society for Opinion and Market Research

clustering of the participants according their LSM level. These two questions were selected corresponding to the LSM which has been used by the South African Audience Research Foundation since 1989 (SAARF 2006). The first question was "Which of these items do you have in working order in your home?" with 19 common electronic devices, such as a kettle or an MP3 player; the second question was "How many of each of the following items do you have in working order in your home?" with 11 items of higher value, such as a TV, laptop computer, or bicycle. The maximum number of points to be reached, which means the ownership of one or more of each of these devices, is 121. These 121 points were divided into six LSM classes with a difference of 20 points each.

Furthermore, two questions were included to get information about the EnAw of the participants: Firstly, "Regarding your environmental concerns, how strongly do you agree with the following statements?", with a five-point scale from "Do not agree" to "Agree strongly," and nine statements regarding waste-disposal, energy saving, and water conservation; and secondly, "How often do you act like in the following list?", with a five-point Likert scale from "Never" to "Always," and 12 sub-points, such as turn off tap, light, or heating. The maximum value reachable for the environmental awareness was 110 points, and the participants, based on the results, were subsequently clustered into six classes (EnAw classes) with a difference of 20 points each.

The survey was first run using Germany as a test country; the other eight countries were surveyed after analyzing the initial results and translating the questionnaire into the respective languages.

The LSM class was assessed to identify correlations with behavior. It was requested to have a spread across all LSM classes within one country; therefore, the average class is not representative of the living standard of the country.

The EnAw class ranges from 2 to 6, with Indonesia on the lowest level (2.69), Germany on the highest (3.51), and an average of 3.1.

The questionnaire consisted of different parts and was split between non-owners and owners of automatic dishwashers. Participants were confronted with a total of 31 questions, partly multiple-choice questions, forced choice (single selection) questions, rating questions, or questions with number insertion. The content of the questions dealt with socio-demographics, dishwashing behavior and motivation, environmental awareness, and questions that allow a social clustering.

The data were analyzed by calculation and comparison of relative frequencies and Pearson's chi-squared test calculated in IBM SPSS Statistics 22 and MS Excel.

Results

Penetration of automatic dishwashers

The spread of automatic dishwashers regarding the countries in this survey is shown in Fig. 1, with a penetration lower than 30% in Argentina, Indonesia, and Brazil; a medium penetration of 30 to 60% in South Africa, Russia, China, and India; and a high penetration of more than 60% in Germany and Italy. Penetration percentages do not reflect the real situation of all countries. The poorest inhabitants are not among the participants as internet access was required for participation. The numbers in India and China are much higher than expected, which might be caused by a confusion of the translated word for dishwasher. The translated word in India might be confused with maids for dishwashing and in China, with sanitizer cupboards.

The overall number of non-owners in this questionnaire is 5249, and is 3565 for automatic dishwasher owners.

The dishwasher penetration, pursuant to the LSM and EnAw class, is presented in Fig. 2. A higher LSM class is clearly correlated with a higher penetration of dishwashers ($R^2 = 0.306$). The correlation is weaker for the environmental awareness class ($R^2 = 0.162$).

Further data show that, on average, only 4.7% of the owners of automatic dishwashers ($n = 3656$) claim to clean everything in the dishwasher. Therefore, almost everybody cleans at least some pieces by hand. Heavy pots or pans (55%), long glasses (54%), and wooden pieces (51%) are most typical for separate manual cleaning. However, dishwasher porcelain, other glass pieces, plastic dishes, ceramic dishes, steel dishes, and pieces with brass coating are also named by more than 25% to be cleaned by hand.

Obstacles against the purchase of an automatic dishwasher are diverse. Figure 3 shows the obstacles perceived named by those who do not own an automatic dishwasher, separately for countries with low, medium or high penetration of automatic dishwashers.

Table 1 Participant characteristics—total participant numbers and average LSM and EnAw class per country

Country	CN	DE	IT	RU	ID	BR	IN	ZA	AR	Total
N (total)	918	1000	997	999	1000	998	996	997	1000	8905
Ø LSM Class	4.58	4.28	4.54	3.80	4.60	4.57	4.85	4.22	4.13	4.40
Ø EnAw Class	2.70	3.51	3.44	3.20	2.69	3.06	3.18	3.35	2.77	3.10

On average, the main argument is the purchase cost, across all countries. Further arguments from the participants of the low penetrated countries are saving costs and energy by cleaning manually (costs: $\chi^2(2) = 44.234$, $p = 0.000$; energy: $\chi^2(2) = 80.730$, $p = 0.000$). The low and medium penetrated countries more often name hygiene and cleaning results as advantages of manual cleaning (more hygienic: $\chi^2(2) = 40.930$, $p = 0.000$; better cleaning results: $\chi^2(2) = 43.124$, $p = 0.000$).

Mistakes in manual dishwashing behavior

Recommended work steps to make manual dishwashing efficient are the collection of dishes instead of cleaning individual items, and to scrape off residues before starting the wash process. A pre-rinsing shall be avoided and the washing itself shall be done in a sink filled with water, as well as the rinsing.

When looking at manual cleaning, there is a high number of non-owners ($n = 5249$) of dishwashers who indicate that they clean individual pieces, either whenever there is a single piece in the sink, or before, during, and after cooking. On average, 85% of the participants do this. The only country not close to this average is Germany, where 60% of the participants indicated that they collect dishes for a bigger washing session.

The scraping off of residues is well spread across the world. On average 75% do this, with lowest percentages in Germany (52%) and highest in Indonesia (91%). The need of scraping off highly depends on country specific dishes on one hand and etiquette on the other. As an example, in China an empty plate is seen as a sign, that the host has not served enough food. In Indonesia, there are many fish and meat dishes served with non-eatable parts as bones. In comparison to that Germany is having a lot of dishes which are free of residues, as bread and salad. And not finishing a plate might be seen as inpolite, interpreted as "your food is not tasty." It is also common to force children to finish their plates by threatening them with bad weather on the next day as a result of the not-finished plate. So a lack of scraping-off might be caused by a lack of need to scrape off.

Mistakes regarding the water consumption in manual dishwashing can be identified for all participants. Figure 4 gives an overview of the occurrence of pre-rinsing and tap-water washing and rinsing in the countries participating in the survey.

The more the water tap is open, the more water and energy (for heating the water) is wasted. However, running tap-water is very common. Pre-rinsing is performed by 44% of the participants overall and 48% of the automatic dishwasher users. Cleaning under running tap-water is carried out by 49% and rinsing under

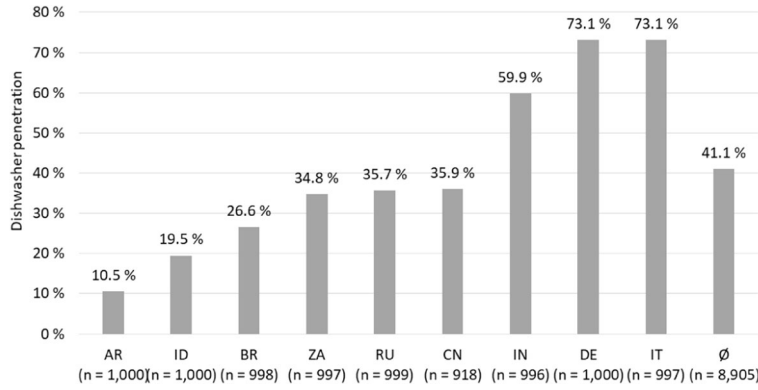

Fig. 1 Dishwasher penetration in the panel across the countries

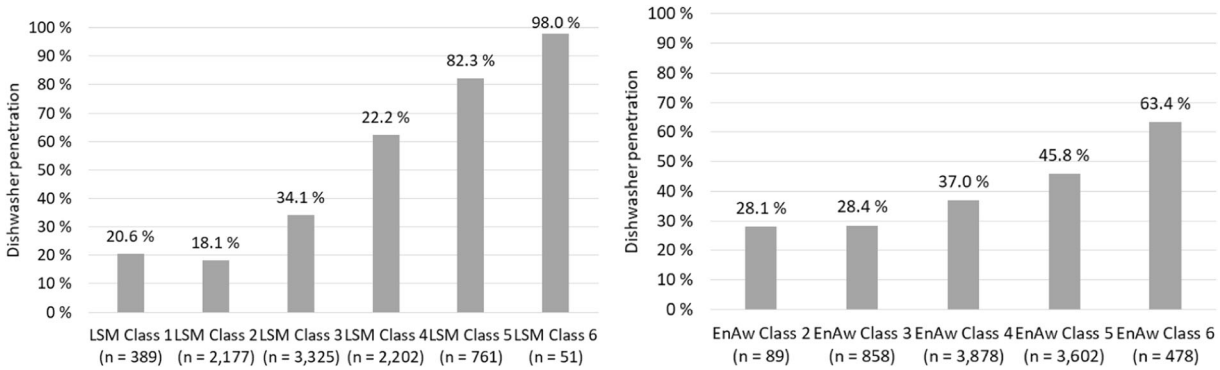

Fig. 2 Dishwasher penetration in correlation with LSM class and environmental awareness class ($n = 8905$)

running tap-water by 39% of the participants. A lower occurrence of running tap-water use can be seen for Germany (all steps under 30%) and South Africa (often pre-rinsing, but under 25% using running tap-water during cleaning and rinsing). No correlation to the environmental awareness classes is observable. A possible reason for the country-specific highest tendency to water saving in Germany might be caused by the fact that household work is mostly learned unconsciously during childhood and therefore a typical cleaning behavior is not caused by attitude but just done by habit (Maitra et al. 2017). This makes it hard to be changed by educational work at a later stage.

A further factor for energy saving is the use of a proper water temperature, as fat is dissolved by warm water. However, an increase in the water temperature for cleaning more fatty dishes is used by only 34% of the overall participants. This is mainly performed in Argentina (52%) and is very uncommon in China (16%). No correlation to the environmental awareness classes can be identified.

Motivators for adaption of dishwashing techniques

At the end of the questionnaire, participants were asked for what reasons they would change their dishwashing

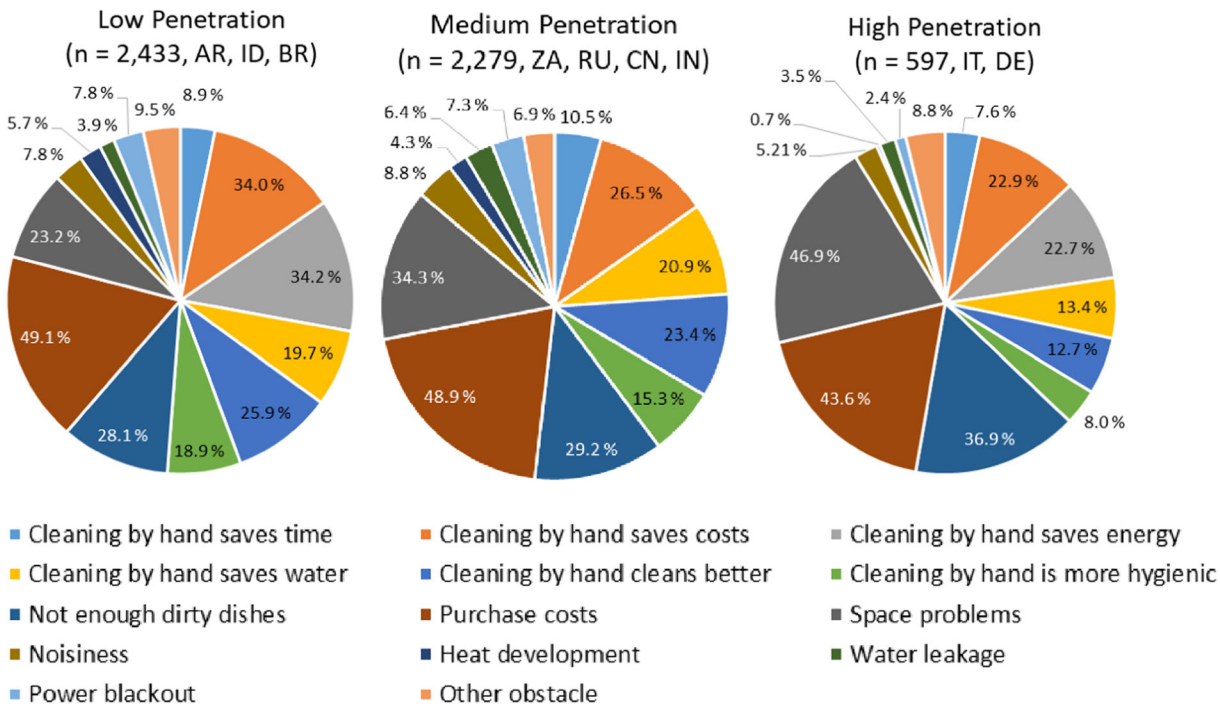

Fig. 3 Comparison of obstacles in differently penetrated country groups (non-users $n = 5249$)

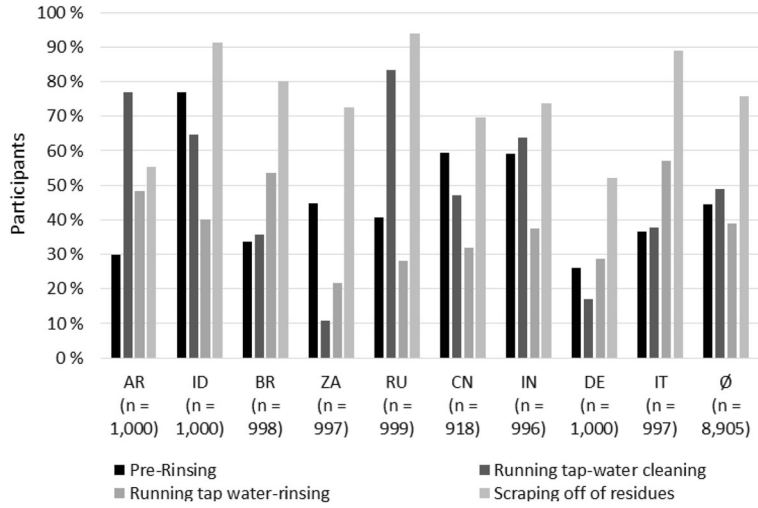

Fig. 4 Running tap-water and residue removal during dishwashing

behavior, with answer options including external reasons, such as costs and water scarcity; and personal motivators, such as new tips from relatives and the chance to save time and effort.

Water and energy rank low in this question. Increasing water and energy costs are not seen as motivators. Figure 5 shows that only 22% of the participants would be motivated to change their dishwashing behavior by increasing water costs and 16% by energy costs. A perceived scarcity of water is named more often by 29%. The "winning" motivator is the chance to save time, obtain better cleaning results or work less physically, with 38% or more participants naming these answer options.

Discussion

Teaching consumers to live in a sustainable way is not as easy as governments' or organizations' hope. Multiple intervention studies show the variety of ideas to bring consumers to a more sustainable behavior, and these are mostly successful regarding raising knowledge and perception of the topic, but not yet equally successful concerning behavioral change (Abrahamse et al. 2005). This shows the complexity and importance of such educational actions. The first step must be to identify a concrete area for improvement. This survey focusing on dishwashing uncovers the water wastage during that part of household work.

While earlier studies have shown the need to teach consumers about the correct program choice when using their automatic dishwasher (Bichler et al. 2015), this study adds insight on the behavior in addition to running the dishwasher: pretreatment before running the dishwasher, manual cleaning behavior, and obstacles against the purchase of an automatic dishwasher.

When talking about saving water, it is important to understand the relevance of this topic in a country. Is water stress in a country linked to environmental awareness or are water costs motivating the inhabitants to save water? The countries included in this questionnaire cover regions with different levels of water stress. The World Resources Institute (Gassert et al. 2013) rates Brazil as country with low water stress (ratio of withdrawals to supply < 10%); Russia, Germany, and Argentina as countries with low to medium water stress (ratio 10 to 20%); China with medium to high water stress (ratio 20 to 40%); and Italy, India, Indonesia, and South Africa as countries with high water stress (ratio 40 to 80%). In addition to this information, the environmental awareness of the participants was assessed. Sorted into five classes of environmental awareness, the latter was mostly in the upper middle class 3. The lowest environmental awareness level can be seen for Indonesia (2.69), China (2.70), and Argentina (2.77). All these three countries belong to different classes of water stress: high, medium, or low. A similar picture exists for the countries with the highest environmental awareness class: South Africa (3.35), Italy (3.44), and Germany (3.51)—one country with low water stress and two with high water stress. This indicates that the environmental awareness of the inhabitants seems to be independent of their environmental situation. More

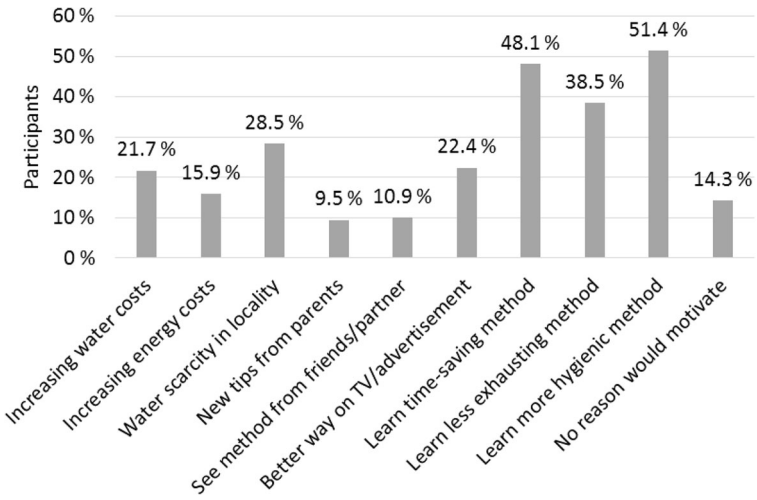

Fig. 5 Reasons that would motivate a change of dishwashing technique ($n = 8905$)

pressure (= more water stress) does not correlate with the adequate attitude (= higher environmental awareness). When looking into data about payment for water, there is also no clear link, that environmental awareness is driven by water costs: In China, Indonesia, and Italy most of the household pay for their water consumption individually by invoice, what might motivate to save water to save costs (Maitra et al. 2017). Italy is showing a high motivation to act environmentally aware, but China does not. In Russia, for comparison, it is typical to pay water along with the community tax, so the individual water consumption is irrelevant for the costs. Russia has an average environmental awareness. When discussing about motivators in the different countries, the water costs can be used as arguments in China, Indonesia, and Italy. In Germany, Italy, and South Africa, the argumentation can be based on the environmental value. Problematic are Russia, Indonesia, and Argentina, where the appraisal is independent of its costs, and therefore the environmental value has to be pointed out.

The LSM class was used to identify correlations with specific behavior. A clear correlation can be seen for the ownership of automatic dishwashers. With a correlation coefficient of 0.306, there is a tendency that the higher the living standard, the more often participants own an automatic dishwasher. The correlation of dishwasher ownership and environmental awareness is smaller, with a correlation coefficient of 0.162; this is similar to the correlation between LSM and environmental awareness. These two aspects correlate positively with 0.137. Therefore, whether consumers with a higher environmental awareness more often own a dishwasher, or it is just the social status that is linked to both a higher awareness and a higher occurrence of dishwashers cannot be clearly defined.

When the non-owners were asked about their reasons for not owning an automatic dishwasher, the main answer goes along with the correlation of living standard and ownership identified the main obstacle for dishwasher ownership is the purchase cost. That this initial cost would become equalized by saving energy and water during the usage phase is not known by the consumers. Many believe that manual cleaning saves costs (17.5% of the non-owners), energy (16.7%), and water (11.5%), and is, additionally, more hygienic or cleans better (9.6 and 13.8%, respectively). These arguments show the lack of knowledge about the advantages of automatic dishwashers and, thus, raising the knowledge could result in an increase of interest in this household appliance. As some countries have a very low penetration of dishwashers, such as Argentina with 10.5% and Indonesia with 19.5%, there is a huge potential to replace manual dishwashing by automatic dishwashing and save a lot of water and energy.

The manual cleaning should also be improved in addition to the required information on the advantages of automatic dishwashers. The results show that manual cleaning is performed in all households, independent of the availability of a dishwasher. Overall, less than 5% of the dishwasher owners indicated that they clean everything in their dishwashers. Therefore, the results regarding the manual cleaning behavior were combined for both groups, the non-owners and the dishwasher owners.

Focusing on the results of manual cleaning behavior, the results help to identify some mistakes where a small behavioral change could end up with relevant resource savings in dishwashing. Firstly, the pre-rinsing, performed before running the dishwasher, reduces the water efficiency of the automatic dishwasher. When no dishwasher is used, it is an unnecessary step, as all soiling can be removed in the cleaning phase.

Cleaning and washing should be carried out in a sink filled with water instead of under running tap-water (Fuß and Stamminger 2010). However, about half of the participants do not act accordingly. Running tap-water is common, especially in Argentina, Russia, and Indonesia. The lowest numbers using running tap-water are counted for Germany and South Africa. South Africa is the country with the highest water stress in this study, but Germany has low to medium water stress, so the external pressure cannot be the reason for the sustainable behavior.

One more opportunity for improvement can be identified by the results: an increase of water temperature for cleaning dishes soiled with fat. Cleaning the latter with cold water requires a lot of water and effort. However, this can be reduced, according to the Sinner circle, by increasing the water temperature (Beck 2008).

The reason why the self-estimated high environmental awareness of the participants does not cause a resource-saving dishwashing behavior can be identified when people are naming motivators for a potential change of their dishwashing technique. While increasing water and energy costs are not very motivating (20% of the participants would be motivated by increasing water costs and 10% by energy costs), the chance to save time, get better cleaning results, or work less physically are real motivators (to 50% for time, 56% for better cleaning, or 40% for physical work of the participants). This shows that the consumers do not perceive their dishwashing as a waste of water or energy, because they do not know a better, more resource-saving technique. This lack of knowledge offers the best chance of real improvement, as people are interested in sustainability, but still need to learn about the impact of their own household work.

Conclusions

This global insight into dishwashing behavior shows the requirements of education in household work. On the one hand, promoting the purchase and use of automatic dishwashers with high-efficiency classes across all social strata is an important step towards more sustainable households. Linked to this, the correct use of dishwashers must become clear to people. Selection of eco programs and no pre-rinsing is essential to benefit from the dishwasher usage.

On the other hand, an increased knowledge about efficient ways of manual cleaning is highly important. This is relevant for all households, not only for those who cannot afford an automatic dishwasher and wash manually. Manual dishwashing is also used, if only for a couple of items. Dishwashing must be performed with less running tap-water at an adequate temperature and with a collected number of dishes over time.

However, as consumers are interested in environmental topics and are cleaning in a resource-wasting way caused by a lack of knowledge about the existence of better techniques, the basis for a successful intervention is evident.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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