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User preferences and water use savings owing to washbasin taps retrofit: A case study of the DECivil building of the University of Aveiro

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ABSTRACT

During the last decades, achieving water efficiency in buildings has increasingly become an important challenge in the scope of sustainability. Water consumption is directly related to individuals conduct. Despite the various technological improvements in fixtures and appliances, their performance will be influenced by human preferences and behavior. As a result, the potential for effective water consumption saving is influenced by behavior change as well as water efficient fixtures and appliances. This work evaluates the impact of user preferences and behavior change on the water efficient performance of tap aerators in a case study building; the Department of Civil Engineering Building of the University of Aveiro, Portugal. Four aerators with different discharge reduction and type were installed in the toilet's washbasins and the user's preferences and behavior change measured through direct and online questionnaires. It was observed that the effective water consumption reduction (15% to 49%) was less than the discharge reduction (30% to 70%), confirming that user factors influence water savings. Water use reductions in the tested range (2.0 l/min to 6.7 l/min) also varied according to gender; with male users using less water than their female counterparts. It was noted that an awareness of sustainability values prevailed amongst the users when confronted with the choice between comfort and water efficiency. Although, differences were observed in the user preferences regarding the various aerators. When confronted with the information that the lower discharge aerator would contribute to a reduction of about 70% on the water discharge, 25% of the users agreed with its use, even if it resulted in a certain degree of dissatisfaction. In comparison, only 8% of the users completely disagreed with its installation. On average, the water consumption reduction was 46% smaller than the discharge reduction achievable with the aerator alone. This further confirms the user factors informs the degree of water savings that is achievable from water efficient fittings and fixtures.

KEYWORDS

Behavioral change; university buildings; user preferences; sustainability; water efficiency

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1. INTRODUCTION

Of the various environmental issues faced by mankind nowadays; shortages and pollution of fresh water resources are amongst the most critical global problems. A significant portion of water consumption takes place in buildings and since it is used to satisfy basic human needs, its requirements in terms of quality tend to be higher when compared to most of the other water uses (e.g., energy production, industry, agriculture). For instance, in Portugal the urban water consumption accounts for only 8% of the total volume of water consumed per year (agriculture accounts for 87%), but represents 48% of the total annual water cost due to the infrastructure needed and resources spent on water treatment and supply (PNEUA N/A). Therefore, the benefits from water saving in buildings have a wider scope, with potentially significant benefits in terms of the consumption of energy and other resources.

Strategies for reducing the amount of water consumed in buildings can be grouped into two categories: i) behavior change; and ii) system change. While the former involves mostly non-structural measures (e.g., education campaigns; water cost; water pricing policies) the later includes structural measures such as water efficient fixtures and appliances retrofit (e.g., Mayer *et al.* 2004, Willis *et al.* 2013), rainwater harvesting (e.g., Tam *et al.* 2010, Ward *et al.* 2013, Silva *et al.* 2015) and water re-use (e.g., Dixon *et al*. 1999, Nolde 2000). Previous planning and management studies that make use of structured integrated water resources management models for water management (e.g., Dvarioniene and Stasiskiene 2007) showed that highly efficient water fixtures and appliances are an economical primary water saving strategy, with recent studies indicating reductions of up to roughly 50% in the USA (Mayer *et al.* 2004), of almost 14% in Australia (Carragher *et al.* 2012) and, in general, between 35 and 50% in the western world (Inman and Jeffrey 2006).

Understanding water consumption and end-use patterns is the starting point for enabling authorities, designers, owners and users to determine where, how often and how much water is used and wasted. However, predicting the water performance due to the implementation of system changes based on the water discharge reduction alone may be prone to significant error. Water consumption and end-use pattern depends not only on the characteristics of the new fixture, appliance or equipment, but also on factors related to the users as individuals and as members of a community and a society (Browne *et al.* 2013). System changes will influence user preferences and may induce behavioral changes, which may affect the benefits of the implemented water efficient measures. For instance, Fidar *et al.* (2016) found that low discharge taps resulted in an increase in water consumption when compared to conventional taps, indicating that the event duration is more relevant to water consumption than the nominal flow rate. Therefore, understanding the determinants influencing water consumption when introducing changes requires the measurement / monitoring of the system performance to enable the efficient planning and operation of water resources through effective policies and adjusted investments (Vieira *et al.* 2007; Makropoulos *et al.* 2008; Fidar *et al.* 2010; Carragher *et al.* 2012; Cole and Stewart 2013).

Based on the critical review by Morrison and Friedler (2014), it was devised that the methods used to measure water consumption and end-use patterns can be organized into three groups: a) direct methods; b) semi-direct methods; and c) indirect methods. Direct methods involve measuring the consumption in each fixture (direct metering). This approach was used by Edwards and Martin (1995) and requires the installation of a meter dedicated to each fixture. In theory, this is the most accurate approach, but the overall system reliability, the metered classes and the costs limit its use. The semi-direct methods are based in high frequency measurement to allow the disaggregation of the signal in order to identify the operation signature of each individual fixture. Larson *et al.* (2012) used a pressure-base sensor (HydroSense) to record the pressure transients and tested two algorithms to identify each particular fixture or appliance pressure signature. This system show promising results, but it can be affected by pressure transients from other sources (e.g., public network, other buildings or apartments) and there is always the issue of the pressure transient signature for partial openings (Morrison and Friedler 2014). The flow trace analysis is conceptually similar approach that uses a signal recognition technique to assign a specific fixture or appliance to each water-use event from high resolution flow data. This technology has been used successfully in several utility sponsored studies (DeOreo *et al.* 1996; Mayer *et al.* 1999, 2002, 2003, 2004; Roberts, 2005; Wilkes *et al.* 2005; Mead and Aravinthan 2009, Willis *et al.* 2010, 2011), as well as in some independent or academic research studies (Mead 2008; Heinrich *et al.* 2007), but it can't distinguish between similar fixtures or appliances (Morrison and Friedler 2014) and loses accuracy when they are used concurrently (Wilkes *et al.* 2005). The Identiflow system is another semi-direct method that identifies and classifies each water-use event of specific fixtures or appliances from flow data using a decision tree algorithm (Kowalski and Marshallsay 2003; Waylan 2008). The system is only available through WRc consultancy services, which report high accuracy results, but the decision three will always fail in anomalous water-use events. It doesn't differentiate between similar fixtures (Clarke *et al.* 2009) and it is prone to human error (Morrison and Friedler 2014). The last group, indirect methods, includes surveys, questionnaires, interviews or other forms of characterization of water consumption and end use from users. These approaches are the most used in practice for their simplicity and low-cost, having been used in several studies (Almeida *et al.* 1999; Butler 1991, 1993; Friedler and Butler 1996; Friedler *et al.* 1996a,b; Silva *et al.* 2015), but are dependent on the willingness of the participants or practical limitations (Morrison and Friedler 2014). Consequently, the results may be inaccurate or biased due to varying levels of participation of different types of participants, fluctuation of the level of participation with time, or possible behavior change due to the awareness of being monitored, amongst other factors (Levallois *et al.* 1998, Parker and Wilby 2013).

This research aims to contribute to existing knowledge by focusing on the evaluation of the user preferences and behavior change from washbasin taps retrofit. The results show the existence of distinct short and long term preferences for female and male users, resulting in different behavioral and water consumption changes depending on the gender of the user.

2. CASE STUDY

Hills *et al.* (2002) stated that tap retrofitting is more viable in public buildings, such as universities, due to their high occupancy. Therefore, the Department of Civil Engineering of the University of Aveiro (DECivil), Portugal, was used as case study. The Department of Civil Engineering (DECivil) building at the University of Aveiro

(Figure 1) is a 3-floor rectangular building, with a total area of 4 320 m^2, comprising of classrooms, offices and laboratories. The building has several water consumption points in the existing toilets and laboratories. The six main toilets (three for female users and three for male users) are responsible for roughly 70% of the building's water consumption, according to previous studies (Gonçalves 2014; Meireles *et al.* 2014). These have 14 washbasins, equally divided between the female and male toilets.

Fig. 1. Aerial and terrestrial view of the DECivil building

There are about 300 individuals (mostly students, but also researchers, professors and administrative and lab workers in the DECivil community. Since this population varies throughout the day and over the academic year, the water consumption pattern varies accordingly. However, except for occasional intensive water-use experiments in the laboratories, the water consumption end-use distribution is fairly uniform. The washbasins consumption accounts for 17% of the water consumption in the toilets (Gonçalves 2014; Meireles *et al.* 2014).

The choice of the DECivil building was due to the dynamics of its community. In particular, the degree of familiarity between the students and the awareness to the relevance of water saving resulted in the willingness to participate in studies in the topic. In the past, the DECivil community has participated in studies including questionnaires regarding their water use (Gonçalves 2014; Meireles *et al.* 2014).

3. MATERIAL AND METHODS

The baseline situation and four different aerators certified by the Portuguese Association for Quality and Efficiency in Building Services (ANQIP) were studied during two subsequent academic years. The baseline situation consisted of the existing laminar flow push taps with an average discharge rate and shut off time of 6.7 l/min and

6.1 seconds, respectively, corresponding to an average water discharge of 0.82 l per use. The four alternative aerators tested had the following characteristics (Figure 2): i) aerator A - aerated flow with Q = 4.7 l/min; ii) aerator B - spray flow with Q = 3.9 l/min; iii) aerator C - aerated flow with Q = 3.4 l/min; and iv) aerator D - spray flow with Q = 2.0 l/min. The aerators studied allow for discharge reductions between 30 and 70% of the discharge rate.

a) b) c) d)

Fig. 2. Characteristics of the different aerators: a) aerator A (aerated flow; Q = 4.7 l/min); b) aerator B (spray flow; Q = 3.9 l/min); c) aerator C (aerated flow; Q = 3.4 l/min); d) aerator D (spray flow; Q = 2.0 l/min)

The method used by Meireles *et al.* (2014) of measuring the tap operation time and the corresponding volume discharged, was used to determine the water discharge rates. The values presented correspond to the average of 4 measurements from each of the 4 taps, with the variation between the highest and lowest average discharges being only 7.6%.

Since the operation time is small and dependent on the pressure each user applies on the tap, it is more prone to higher variability and to error measurement. To evaluate the influence of the user on the tap operation, 20 random users (10 female users and 10 male users) were requested to push 3 different taps twice and the variation of the total water discharged was found to be less than 10%. Additionally, the operation time was measured by two individuals in all experiments and the differences between them were less than 5%. Consequently, it is possible to claim that the operation time is independent of the user and the error in measuring the tap's shut off time is fairly consistent in all measurements.

For the purpose of the present study, the operation time is irrelevant because the comparisons are made based on the water discharge per use and the number of uses. However, since the individuals depends on the discharge rate and the operation time, the values were presented to allow a direct comparison with other studies.

The evaluation of the user preferences and behavior change was performed through two different types of questionnaire: i) direct questionnaires, with enquiries about water consumption behavior and preferences; and ii) online questionnaires, focused only on preference issues. The study was performed during the teaching and exams periods and the average building occupancy was 150 people during the work hours (9 am to 6 pm).

The direct questionnaires were deployed on Tuesdays, from March to May 2015, during the teaching period, to maximize the number of replies, since a previous study reported the largest occupancy of the building on those days (Gonçalves 2014). These questionnaire surveys were carried out from 8:30 am to 6:30 pm, in the toilets with the highest number of uses, which were also the toilets with the most heterogeneous users. The aerators were installed with decreasing discharge (i.e., from A to D) to allow the users a progressive adaptation to the decreasing discharge rate. The new aerators were replaced at the same time, to ensure that all users experienced the same conditions during the inquiry period. The response rate for the directly monitored toilets were 100%, corresponding to about 50 uses per day. Given the size and dynamics of the DECivil building community, this was an expected result and the number of replies per day did not vary significantly during the days of the direct monitoring campaign.

The online questionnaires were carried out in May and June, focusing only on the two lower discharge aerators (aerators C and D) and on the base situation. In this case, the aerators were installed by increasing discharge in order to also evaluate the influence of a decreasing or increasing discharge in the user's consumption behavior, especially since the users were previously introduced to the study during the direct monitoring campaign. Aerator D was installed in every toilet without prior notice at the beginning of week one. At the end of week one, an online questionnaire was made available, and stayed online during week two. Subsequently, aerator D was replaced without prior notice by aerator C in the beginning of week three. At the end of week three, a new online questionnaire was made available, and stayed online during week four. In the beginning of week five, the base situation was again restored and an online questionnaire was made available during week six. Weeks one and two corresponded to the teaching period, weeks three and four to break and exams periods and weeks five and six to exams period. The reply rate of the online questionnaires varied between 29% and 35% of the total DECivil building occupants, representing roughly 90 responses per questionnaire. A decreasing trend in the replies to questionnaires 1 to 3 was observed, which may in part be explained by the fact that they were performed at different academic periods. More information can be found in (Oliveira 2015).

The statistical analysis of the data collected was carried out using Excel and SPSS software. In addition to the calculation of descriptive statistics (e.g., average) the statistical significance of the differences on the mean water consumption, mean number of tap pushes and mean preference due to the aerators and gender was evaluated through parametric methods such as the analysis of variance (ANOVA) and t-test. The homogeneity of variance assumption underlying the ANOVA was assessed using the Levene's test. In the cases where the assumption was violated, the Brown-Forsythe and Welch statistic were computed in alternative to the F statistic of the ANOVA. Depending on the sample size, the Kolmogorov-Smirnov or the Shapiro-Wilk were used to test for normality. Since the ANOVA only tests the existence or not of statistically significant difference between any of the groups, the Games-Howell and Tukey HSD post-hoc test was applied to identify which of the groups were statistically different and quantify the difference in terms of water consumption and number of pushes. The Games-Howell test accounts for unequal variances and group sizes, whereas the Tukey HSD may have more power. For the comparison of only two groups the t-test was used instead of the ANOVA. When the parametric methods applicability failed (assumptions violation), the non-parametric statistical tests Kruskal-Wallis and Mann-Whitney were used as complements. The Chi-Squared test for independence was applied to evaluate sample differences in terms of age and gender distributions. The statistical significance of the results was evaluated against a 5% significance level, i.e., the results were considered to be statistically significant when $p < 0.050$.

4. Results and discussion

4.1 Consumption reduction

The potential population of users in each monitoring campaign was the same, but there was no way to ensure the samples to be statistically equivalent at the onset. By using the Chi-Squared test to compare the sample of users in each monitoring campaign, it was found there were no statistically significant differences in terms of age ($\chi^2(15)=11.572$, p=0.711) and gender ($\chi^2(4)=2.306$, p=0.680).

Independently of the aerator used, a reduction in water consumption was observed when compared to the base situation (Figure 3). Still, the reduction is not linear, with a significant reduction with aerator A but no additional reduction with aerator B and then further reduction with aerators C and D. Comparing the results of aerators A and B, the only possible explanation based on the information available is that the type of flow (aerated or spray) also affects the amount of water use. However, between aerators C and D the same was not observed, indicating that other factors may exist.

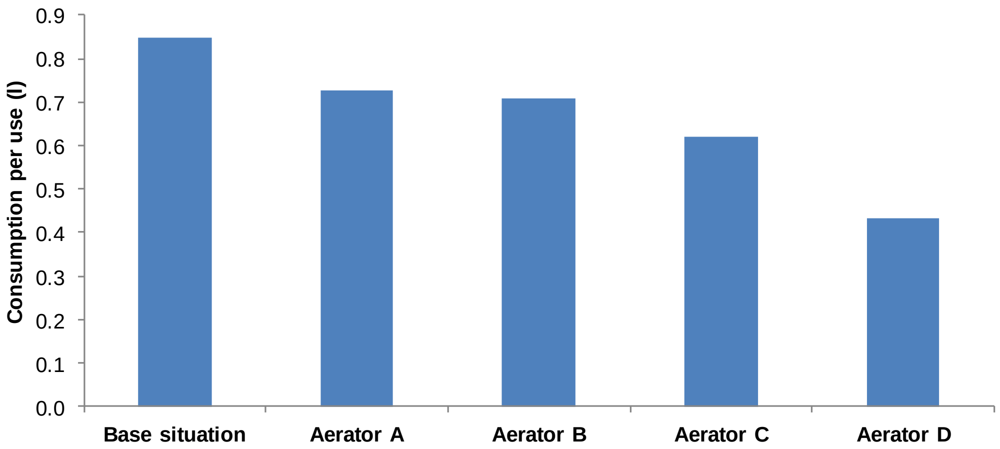


Fig. 3. Comparison of the average water consumption per use for the base situation and tested aerators

A statistically significant difference in consumption was found between aerators and base situation as determined by one-way ANOVA (F(4,715)=16.280, p=0,000). Levene's test indicated unequal variances (F(4,715)=5.155, p=0,000), but both the Welch (F(4,113.3)=40.183, p=0,000) and the Brown-Forsythe (F(4,217.2)=25.536, p=0,000) confirm that there is a statistically significant difference in the rates of consumption. Both the Tukey HSD and the Games-Howell post-hoc test revealed that the consumption was statistically and significantly lower with aerators C (0.62 ± 0.29 l, p=0.000) and D (0.43 ± 0.17 l, p=0.000) compared to the base situation (0.84 ± 0.36 l). Aerator D (0.43 ± 0.17 l) was also found to produce a statistically significant lower consumption than aerators A (0.72 ± 0.28 l, p=0.000), B (0.71 ± 0.32 l, p=0.000) and C (0.62 ± 0.29 l, p=0.000). There were no statistically significant differences between the aerators A and B (p=1.000), A and C (p=0.537) and B and C (p=0.687). The p-values presented were the highest between both tests.

The Kolmogorov-Smirnov test indicated that the consumption rate also violates the assumption of normality in the base situation (K-S=0.362, p=0.000) and for all aerators (A: K-S=0.256, p=0.000; B: K-S=0.228, p=0.000; C: K-S=0.199, p=0.000; D: K-S=0.291, p=0.000). Since the number of cases in each group is higher than 15 (minimum 35), the results of the ANOVA are still valid. Nevertheless, the Kruskal-Wallis test (H(4)=88.723, p=0.000) also indicates a statistically significant difference on consumption between aerators and base situation.

On average, the water consumption reduction was 46% smaller than the discharge reduction achieved with the aerator. In fact, while the aerators contributed to discharge reductions between 30% and 70%, the reduction on water consumption was only between 15% and 49% (Table 1).

Table 1. Relation between discharge and consumption reduction

Aerator	Discharge reduction	Consumption reduction	Rel. diff. discharge and consumption reduction
A	30%	15%	51%
B	42%	17%	60%
C	49%	27%	44%
D	70%	49%	30%

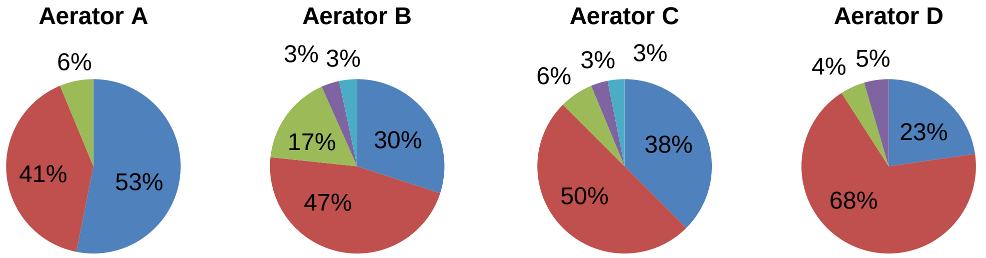
4.2 Gender differences

These differences resulted from water use actions by the users, namely the number of tap pushes in each use. However, the change was not uniform with the gender. Whilst a distinct difference was observed in male users' (Figure 4 a)), female users consistently operated the taps the same number of times, independently of the aerator (Figure 4 b)). For instance, while 33% to 37% of the female users operated the taps once for all aerators, 53% of the male users operated the tap once when aerator A was installed, against 30% for aerator B, 38% for aerator C and 23% for aerator D. Further, a distinct difference was also observed when the base situation is compared to the tested aerator situations, as is noticeable when Figure 4 is compared with Figure 5.

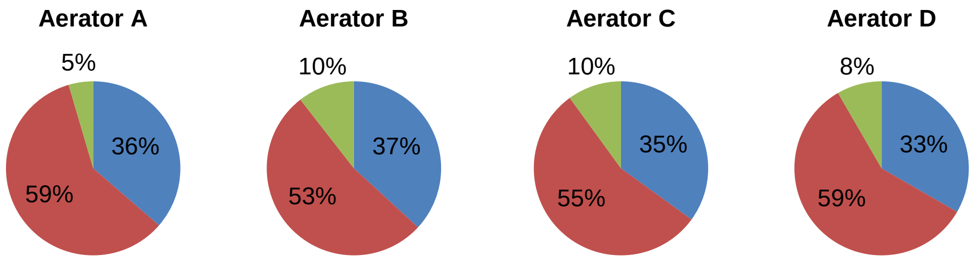
There is a statistically significant difference in the number of tap pushes between aerators and base situation as determined by one-way ANOVA for both male users (F(4,466)=22.645, p=0,000) and female users (F(4,244)=6.566, p=0,000). Levene's test indicated unequal variances only for male (F(4,466)=6.295, p=0,000), but both the Welch (F(4,58.1)=12.661, p=0,000) and the Brown-Forsythe (F(4,106.8)=12.737, p=0,000) tests confirm that there is a statistically significant difference on the number of tap pushes. For female users, the Tukey HSD post-hoc test revealed that the number of tap pushes was statistically significant different only with aerators B (1.74 ± 0.65 tap pushes, p=0.043), C (1.75 ± 0.64 tap pushes, p=0.028) and D (1.92 ± 0.86 tap pushes, p=0.007) compared to the base situation (1.31 ± 0.62 tap pushes). The Games-Howell test did not identify any statistically significant difference on the number of pushes for female users for a 5% significance level. However, the maximum p-value obtained was 0.088, except for aerator D (p=0.151), indicating that the results were close to be significant. For male users, the Tukey HSD and Games-Howell post-hoc tests revealed that the number of tap pushes was statistically significant different only with aerators B (2.03 ± 0.96 tap pushes, p=0.001), C (1.84 ± 0.92 tap pushes, p=0.009) and D (1.91 ± 0.68 tap pushes, p=0.002) compared to the base situation (1.25 ± 0.51 tap pushes). The p-values presented were the highest between both tests.

The Shapiro-Wilk or Kolmogorov-Smirnov tests indicate that the number of tap pushes by female users also violates the assumption of normality in the base situation (K-S=0.444, p=0.000) and all aerators (A: S-W=0.613, p=0.000; B: S-W=0.784, p=0.001; C: S-W=0.780, p=0.000; D: S-W=0.808, p=0.000). The same occurs for male users (base situation: K-S=0.467, p=0.000; aerator A: S-W=0.718, p=0.000; aerator B: S-W=0.826, p=0.000; C: S-W=0.748, p=0.000; D: S-W=0.719, p=0.000). Since the number of cases in each group is only less than 15 in one case (minimum 13 for female users using aerator D), the results of the ANOVA are still valid. Nevertheless, the Kruskal-Wallis test also indicates a statistically significant difference on the number of tap pushes for both female (H(4)=32.854, p=0.000) and male users (H(4)=75.999, p=0.000).

It was observed that male and female users reacted differently to the discharge reduction. Male users adjusted their behavior in terms of the number of times the tap is operated in each use to compensate the reduction in water discharge introduced by the aerators. In practice, this meant that the volume of water per use was reduced by only about 10% in the interval of discharges between 3.9 and 6.7 l/min and that volume of water per use reduction was only effective for the aerators with lower discharges. The reduction in water consumption was 22% and 48% for the aerators with discharges of 3.4 and 2.0 l/min, respectively. Female user behavior, on the other hand, was less affected by the discharge reduction in the tested interval (2.0 to 6.7 l/min). As a result, the water consumption reduction was closer to the theoretical water discharge reduction, being higher with female users - between 19 and 50% (Figure 6).



a)



b)

■1 ■2 ■3 ■4 ■5

Fig. 4. Number of tap pushes per use for a) male and b) female users

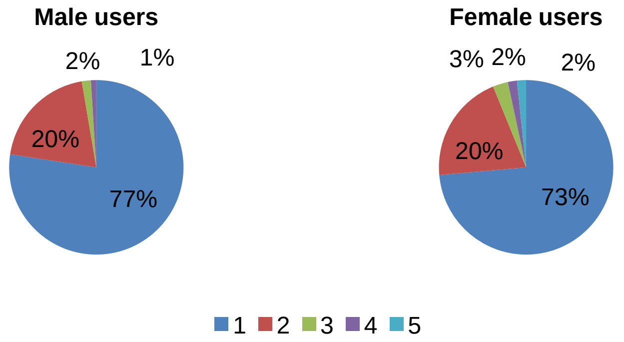


Fig. 5. Number of tap pushes per use for the base situation according to gender

For the base situation and for each aerator separately there was no statistically significant difference on number of tap pushes by female and male users both using ANOVA and Mann-Whitney U tests. However, when the relative differences between the proportions of uses by number of tap pushes per gender for all scenarios were compared, it can be concluded that there were cases with statistically significant differences. The t-test was statistically significant from the base situation to aerator B (t(4)=5.37, p=0.006) and C (t(4)=4.05, p=0.015) and from aerator A to aerator C (t(4)=2.99, p=0.040). All other cases were not statistically significant, but the maximum p-value was only 0.14. Adopting a less stringent significance level (e.g., 0.1 or 0.15) would yield that most or all cases could be regarded as statistically distinct. Additionally, the taps do not have the same discharge or shut off time, resulting in different consumption per use. There were statistically significant differences in the consumption per use by gender as determined by the Mann-Whitney U test for the base situation (U=34 446.00, p=0.038) and aerator B (U=434.00, p=0.002), C (U=452.00, p=0.012) and D (U=210.00, p=0.022), but not for aerator A (p=0.076).

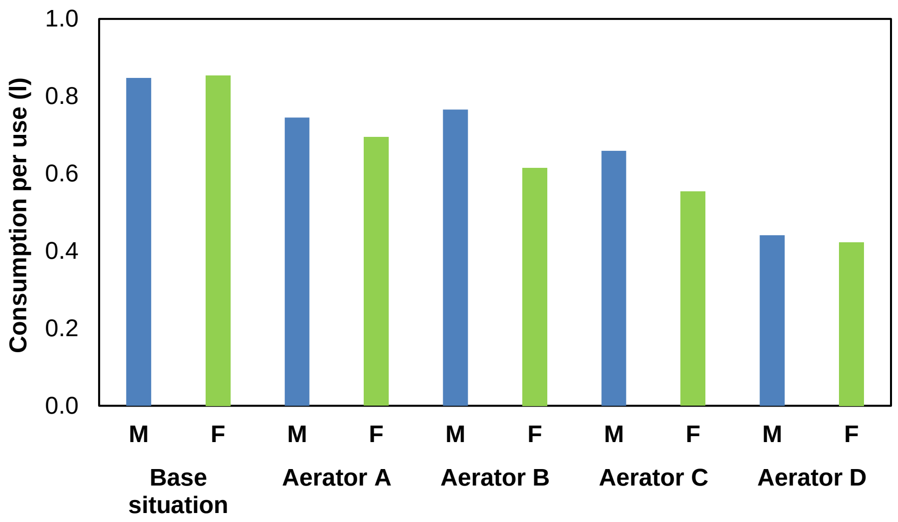


Fig. 6. Comparison of the consumed volume of water per use for the base situation and tested aerators, per gender (M for male users and F for female users)

The female users have a fairly linear relation between water consumption reduction and discharge reduction, whereas male users do not respond linearly to this relation with more distance between direct proportion between consumption and discharge reduction (Figure 7).

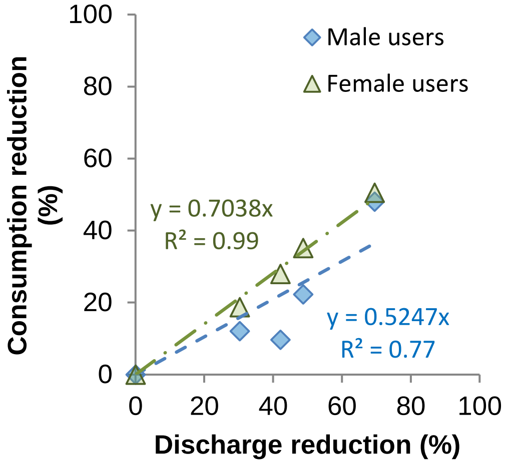


Fig. 7. Comparison between discharge reduction and consumption reduction by gender

It is also interesting to notice that, although female users consumed less water per use with any of the tested aerators, their consumption for the base situation was fairly equal to the consumption of male users. It should be noticed that, despite the difference observable in the discharge pattern between the base situation and the aerators (also between aerators but less noticeable), the installation of the aerators was not publicized neither any information regarding their performance provided. Therefore, the probability of behaviour change due to the fact of being under study is expected to be reduced.

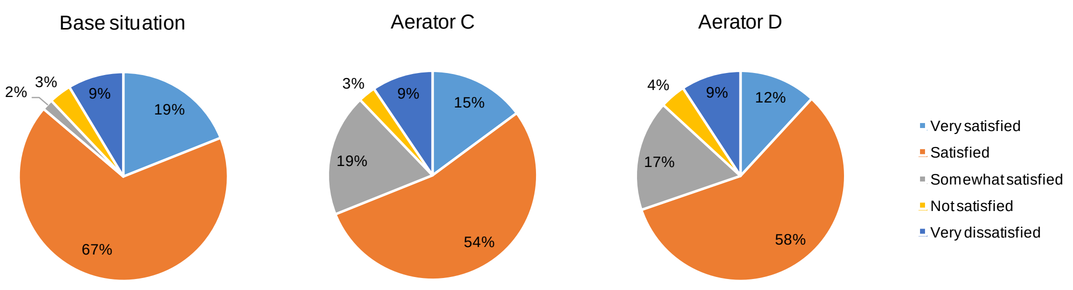
4.3. User preferences

The users were requested to rank their use preference for each aerators in terms using a scale from 1 to 5 (1 - very dissatisfied; 2 - not satisfied; 3 - somewhat satisfied; 4 - satisfied; 5 - very satisfied) in the direct questionnaires, which were carried out coincidently with the installation of the aerators. None of the users classified any of the aerators as very dissatisfying (classification 1). The exceptions are aerators C and D which some users (less than 10%) considered their use not satisfying (classification 2). On the contrary, more than 45% of the users said that they were very satisfied about the use of any of the aerators.

In addition, the online questionnaires gauged user preferences after a usage period of at least one week. In the online questionnaires, the professional position data e.g. undergraduate student, graduate student, researcher, professor or staff was also obtained. Again, since there was no control over the users replying to each online questionnaire, the Chi-Squared test was performed to compare the sample of users in each. There were no statistically significant differences in terms of age ($\chi^2(10)=6.603$, $p=0.762$), professional position (χ^2 $(8)=5.270$, $p=0.728$) and gender ($\chi^2(2)=0.689$, $p=0.709$) between the samples of users replying to each online questionnaire.

The respondents perception of discharge change and preference results were found to be statistically significant between the base situation and with aerators (perception: $\chi^2(2)=18.138$, $p=0.000$; preference: $\chi^2(8)=15.852$, $p=0.045$). Between aerators, the respondents had a statistically weak perception of discharge change ($\chi^2(1)=3.217$, $p=0.073$) and there was no statistically significant difference on the preference results ($\chi^2(4)=0.601$, $p=0.963$).

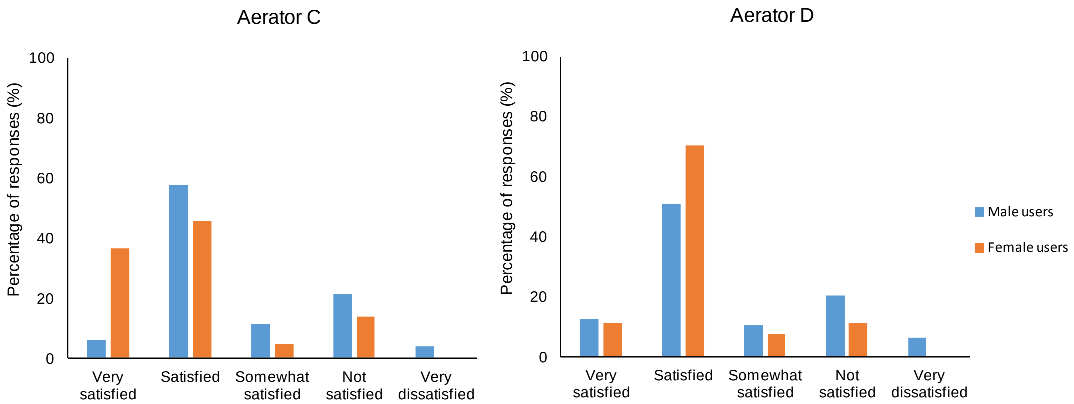
Not more than 15% of the online questionnaire respondents stated that they were very satisfied with the use of aerators C and D (Figure 8), as opposed to the 46 and 45% of the users in the direct questionnaire. A possible explanation may be from the fact that for the direct questionnaires, the aerators were installed by decreasing discharge, with the users having time to progressively adapt to smaller discharges, while in the online questionnaires the aerators were installed by increasing discharge, and the users were faced with the lowest discharge immediately. Nonetheless, only about 12% of the users negatively classified aerators C and D in the online questionnaires, compared to about 70% that considered these aerators satisfying or very satisfying. In addition, no more than 20% considered the base situation very satisfying and 5% classified it negatively, even without reports of water splashing occurrences.



a) b) c)

Fig. 8. Users preferences: a) base situation; b) aerator C; c) aerator D

In the base situation, the perception of preference between male and female users was not statistically different ($\chi^2(4)=2.436$, $p=0.656$), but it became so with the aerators ($\chi^2(4)=9.236$, $p=0.050$). On average, 26% of male users considered the use of aerators C and D not satisfying, against 12% of female users (Figure 9). In addition, aerators C and D obtained roughly the same percentage of positive responses by gender, although the distribution between "satisfying" and "very satisfying" was very different. In fact, although 82% of female users and 63% of male users classified each of the aerators C and D positively, male users gave better classification to aerator D, while female users' classified aerator C better.



a) b)

Fig. 9. Users level of satisfaction per gender: a) aerator C; b) aerator D

Users were then asked which aerator would serve them better. Around 50% preferred aerator D to aerator C, against 28% which made aerator C their first choice (Figure 10). These numbers are notable, not only because aerator D provides a smaller discharge than aerator C, showing that the type of flow is very important for the user preference, but also because the discharge of aerator D is under the limit of 3-4 l/min recommended by ANQIP for washbasin taps in general, in order to attain a minimum level of satisfaction.

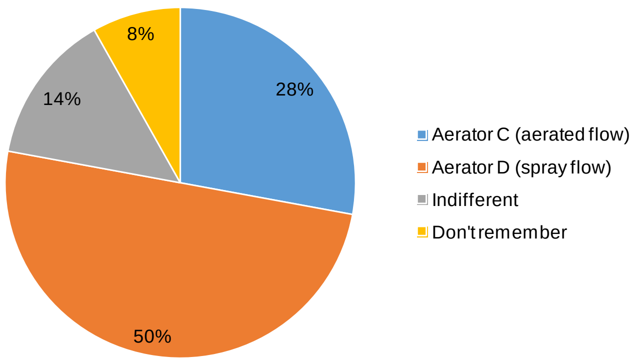


Fig. 10. Users choice based on their preferences

The Chi-Square test of the preference with the age and professional position of the respondents also resulted in a $p<0.1$, but a significant number of the classes of this variables had less than 5 replies, hindering any conclusion.

4.3. Attitude to saving water

A question on attitude to saving water was posed in the first two online questionnaires, to further explore the feedback on aerator D (or C, for questionnaire 2) and the extent to which they contribute to a discharge reduction of approximately 70% (or 50%, for questionnaire 2) (Figure 11). 25% of the respondents agreed with the use of the aerator D, even if they considered it to be not satisfying, against only 8% of the respondents disagreeing completely with its installation. The remaining 67% agreed with the use of the aerator since they did not feel dissatisfied about the use of this appliance. Similar conclusions were attained for aerator C.

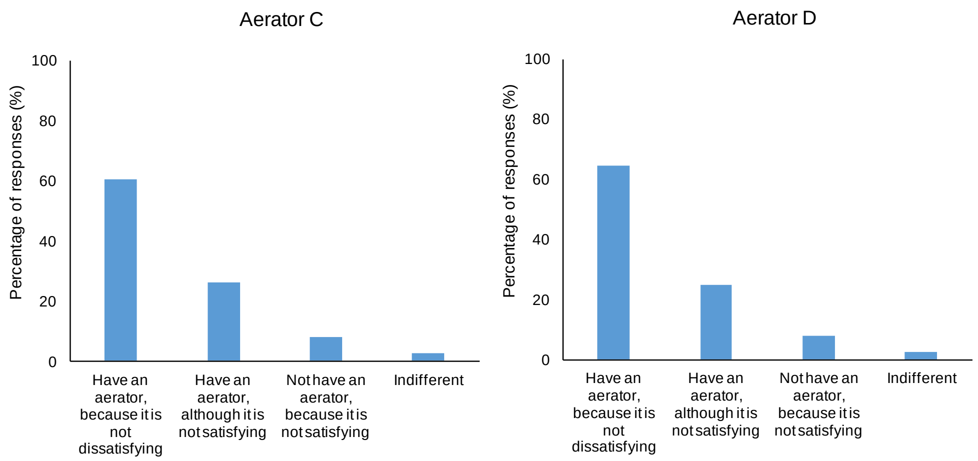


Fig. 11. Attitude to saving water: a) aerator C; b) aerator D

5. CONCLUSION

The present study found that water use actions and behaviors as well as user preferences affect the degree of water savings that is achieved from water efficient fixtures and fittings as demonstrated by the case study; washbasin taps retrofit. As a consequence, the water consumption reduction potential due to the water discharge reduction of the tested aerators was never fully used because the use pattern changed to compensate for the lower discharge. Nonetheless, a threshold of acceptance was found for certain aerators based on water discharge rates. Aerators that were below the 4l threshold received higher dissatisfaction rates compared to the others.

It was also found that the water use action changes and preferences are different per gender and duration of exposure. Female users were found to be less sensitive than male users to the water discharge reduction between aerators, leading to a higher water consumption reduction by the former. Male users adjusted their behavior to compensate for the discharge reduction, resulting in a marginal water consumption reduction for aerators A and B, with the discharge reduction being compensated by the increase in the number of pushes. For aerator C was observed a decrease in water consumption by male users, but water consumption was still higher than for their female counterparts. The water consumption with aerator D is the lowest and similar for female and male users.

In addition, the users have distinct preferences when confronted with the water efficiency measures for the first time and in the short term (one to two weeks).

The results demonstrate that the assessment of the performance of water efficiency measures is highly dependent on users; preferences, actions and reactions. Therefore, the determination of water consumption reduction based on estimated (theoretical) water discharge rates may result in high error, at least on the short term. Lastly, an existing positive attitude on the action to save water was observed among users in general. Future research will aim to further evaluate how the behavior and preferences evolve with time as the users adjust to a new water discharge pattern and system.

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