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

3
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14
15 **ABSTRACT**

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

35

36 **KEYWORDS**

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

38

39 **ACKNOWLEDGEMENTS**

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43 Polytechnique Fédérale de Lausanne, during which part of the analysis was carried out.

44

45 1. INTRODUCTION

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

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

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

77 Based on the critical review by Morrison and Friedler (2014), it was devised that the methods used to measure
78 water consumption and end-use patterns can be organized into three groups: a) direct methods; b) semi-direct
79 methods; and c) indirect methods. Direct methods involve measuring the consumption in each fixture (direct

80 metering). This approach was used by Edwards and Martin (1995) and requires the installation of a meter dedicated
81 to each fixture. In theory, this is the most accurate approach, but the overall system reliability, the metered classes
82 and the costs limit its use. The semi-direct methods are based in high frequency measurement to allow the
83 disaggregation of the signal in order to identify the operation signature of each individual fixture. Larson *et al.*
84 (2012) used a pressure-base sensor (HydroSense) to record the pressure transients and tested two algorithms to
85 identify each particular fixture or appliance pressure signature. This system show promising results, but it can be
86 affected by pressure transients from other sources (e.g., public network, other buildings or apartments) and there
87 is always the issue of the pressure transient signature for partial openings (Morrison and Friedler 2014). The flow
88 trace analysis is conceptually similar approach that uses a signal recognition technique to assign a specific fixture
89 or appliance to each water-use event from high resolution flow data. This technology has been used successfully
90 in several utility sponsored studies (DeOreo *et al.* 1996; Mayer *et al.* 1999, 2002, 2003, 2004; Roberts, 2005;
91 Wilkes *et al.* 2005; Mead and Aravinthan 2009, Willis *et al.* 2010, 2011), as well as in some independent or
92 academic research studies (Mead 2008; Heinrich *et al.* 2007), but it can't distinguish between similar fixtures or
93 appliances (Morrison and Friedler 2014) and loses accuracy when they are used concurrently (Wilkes *et al.* 2005).
94 The Identiflow system is another semi-direct method that identifies and classifies each water-use event of specific
95 fixtures or appliances from flow data using a decision tree algorithm (Kowalski and Marshallsay 2003; Waylan
96 2008). The system is only available through WRc consultancy services, which report high accuracy results, but
97 the decision three will always fail in anomalous water-use events. It doesn't differentiate between similar fixtures
98 (Clarke *et al.* 2009) and it is prone to human error (Morrison and Friedler 2014). The last group, indirect methods,
99 includes surveys, questionnaires, interviews or other forms of characterization of water consumption and end use
100 from users. These approaches are the most used in practice for their simplicity and low-cost, having been used in
101 several studies (Almeida *et al.* 1999; Butler 1991, 1993; Friedler and Butler 1996; Friedler *et al.* 1996a,b; Silva *et*
102 *al.* 2015), but are dependent on the willingness of the participants or practical limitations (Morrison and Friedler
103 2014). Consequently, the results may be inaccurate or biased due to varying levels of participation of different
104 types of participants, fluctuation of the level of participation with time, or possible behavior change due to the
105 awareness of being monitored, amongst other factors (Levallois *et al.* 1998, Parker and Wilby 2013).
106 This research aims to contribute to existing knowledge by focusing on the evaluation of the user preferences and
107 behavior change from washbasin taps retrofit. The results show the existence of distinct short and long term
108 preferences for female and male users, resulting in different behavioral and water consumption changes depending
109 on the gender of the user.

110

111 **2. CASE STUDY**

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

115 (Figure 1) is a 3-floor rectangular building, with a total area of 4 320 m², comprising of classrooms, offices and
116 laboratories. The building has several water consumption points in the existing toilets and laboratories. The six
117 main toilets (three for female users and three for male users) are responsible for roughly 70% of the building's
118 water consumption, according to previous studies (Gonçalves 2014; Meireles *et al.* 2014). These have 14
119 washbasins, equally divided between the female and male toilets.



120

121

122

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

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

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

132

133 3. MATERIAL AND METHODS

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

137 6.1 seconds, respectively, corresponding to an average water discharge of 0.82 l per use. The four alternative
138 aerators tested had the following characteristics (Figure 2): i) aerator A - aerated flow with $Q = 4.7$ l/min; ii) aerator
139 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
140 with $Q = 2.0$ l/min. The aerators studied allow for discharge reductions between 30 and 70% of the discharge rate.
141



142 a) b) c) d)
143 Fig. 2. Characteristics of the different aerators: a) aerator A (aerated flow; $Q = 4.7$ l/min); b) aerator B (spray
144 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)
145

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

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

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

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

164 The direct questionnaires were deployed on Tuesdays, from March to May 2015, during the teaching period, to
165 maximize the number of replies, since a previous study reported the largest occupancy of the building on those
166 days (Gonçalves 2014). These questionnaire surveys were carried out from 8:30 am to 6:30 pm, in the toilets with
167 the highest number of uses, which were also the toilets with the most heterogeneous users. The aerators were

168 installed with decreasing discharge (i.e., from A to D) to allow the users a progressive adaptation to the decreasing
169 discharge rate. The new aerators were replaced at the same time, to ensure that all users experienced the same
170 conditions during the inquiry period. The response rate for the directly monitored toilets were 100%, corresponding
171 to about 50 uses per day. Given the size and dynamics of the DECivil building community, this was an expected
172 result and the number of replies per day did not vary significantly during the days of the direct monitoring
173 campaign.

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

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

202 terms of age and gender distributions. The statistical significance of the results was evaluated against a 5%
203 significance level, i.e., the results were considered to be statistically significant when $p < 0.050$.

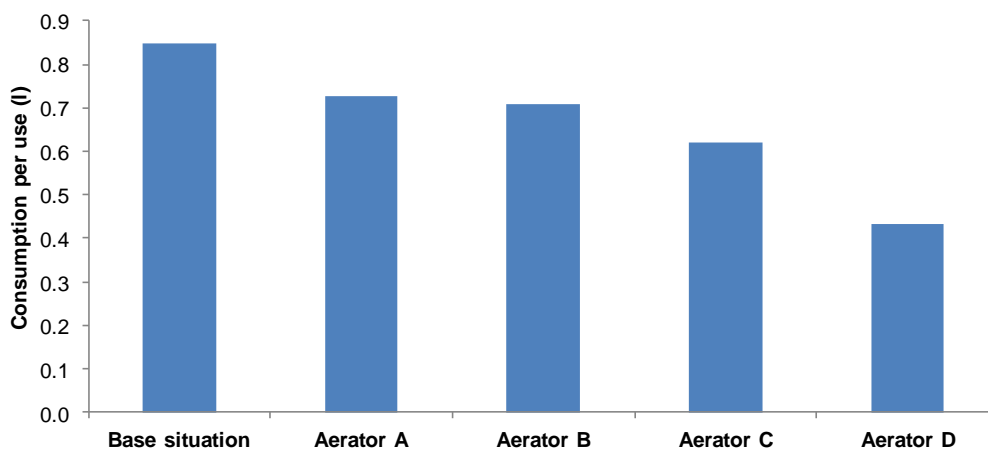
204

205 4. Results and discussion

206 4.1 Consumption reduction

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

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



217

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

219

220 A statistically significant difference in consumption was found between aerators and base situation as determined
221 by one-way ANOVA ($F(4,715)=16.280$, $p=0,000$). Levene's test indicated unequal variances ($F(4,715)=5.155$,
222 $p=0,000$), but both the Welch ($F(4,113.3)=40.183$, $p=0,000$) and the Brown-Forsythe ($F(4,217.2)=25.536$,
223 $p=0,000$) confirm that there is a statistically significant difference in the rates of consumption. Both the Tukey
224 HSD and the Games-Howell post-hoc test revealed that the consumption was statistically and significantly lower
225 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
226 l). Aerator D (0.43 ± 0.17 l) was also found to produce a statistically significant lower consumption than aerators
227 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

228 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
 229 p-values presented were the highest between both tests.

230 The Kolmogorov-Smirnov test indicated that the consumption rate also violates the assumption of normality in the
 231 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
 232 35), the results of the ANOVA are still valid. Nevertheless, the Kruskal-Wallis test ($H(4)=88.723$, $p=0.000$) also
 233 indicates a statistically significant difference on consumption between aerators and base situation.
 234

235 On average, the water consumption reduction was 46% smaller than the discharge reduction achieved with the
 236 aerator. In fact, while the aerators contributed to discharge reductions between 30% and 70%, the reduction on
 237 water consumption was only between 15% and 49% (Table 1).
 238

239 **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%

240

241 **4.2 Gender differences**

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

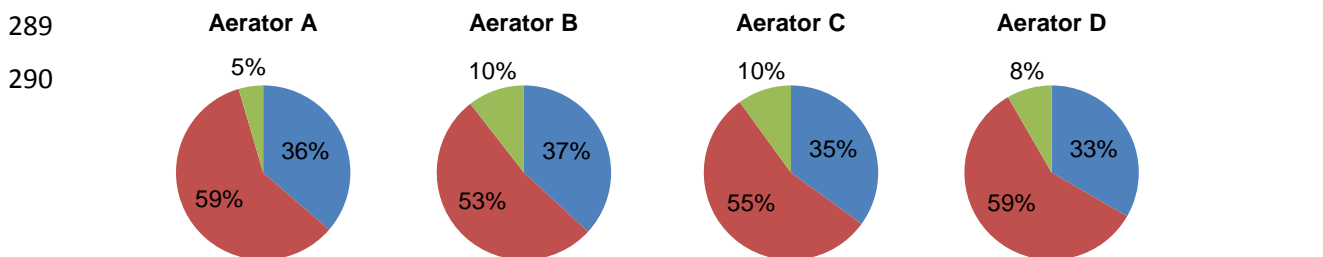
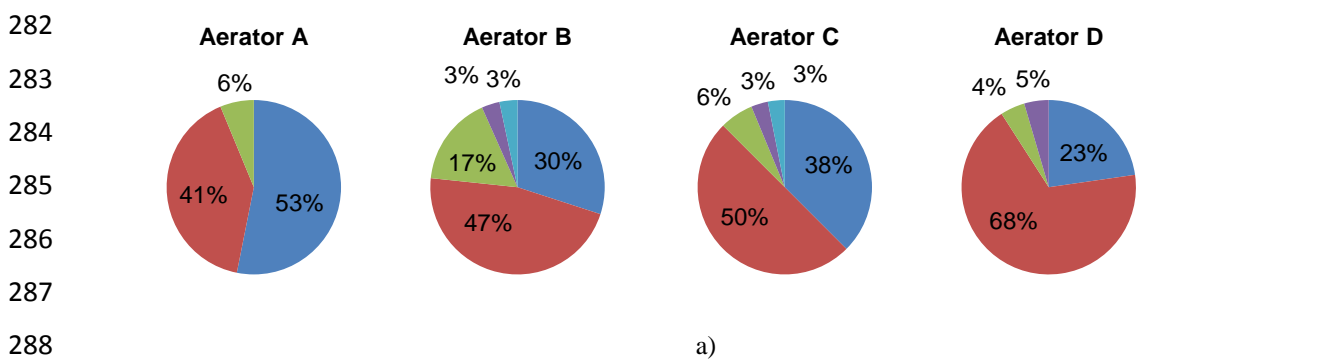
249 There is a statistically significant difference in the number of tap pushes between aerators and base situation as
 250 determined by one-way ANOVA for both male users ($F(4,466)=22.645$, $p=0,000$) and female users
 251 ($F(4,244)=6.566$, $p=0,000$). Levene’s test indicated unequal variances only for male ($F(4,466)=6.295$, $p=0,000$),
 252 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
 253 confirm that there is a statistically significant difference on the number of tap pushes. For female users, the Tukey
 254 HSD post-hoc test revealed that the number of tap pushes was statistically significant different only with aerators
 255 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, $p=0.007$)

256 compared to the base situation (1.31 ± 0.62 tap pushes). The Games-Howell test did not identify any statistically
 257 significant difference on the number of pushes for female users for a 5% significance level. However, the
 258 maximum p-value obtained was 0.088, except for aerator D ($p=0.151$), indicating that the results were close to be
 259 significant. For male users, the Tukey HSD and Games-Howell post-hoc tests revealed that the number of tap
 260 pushes was statistically significant different only with aerators B (2.03 ± 0.96 tap pushes, $p=0.001$), C (1.84 ± 0.92
 261 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
 262 pushes). The p-values presented were the highest between both tests.

263 The Shapiro-Wilk or Kolmogorov-Smirnov tests indicate that the number of tap pushes by female users also
 264 violates the assumption of normality in the base situation ($K-S=0.444$, $p=0.000$) and all aerators (A: $S-W=0.613$,
 265 $p=0.000$; 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
 266 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:
 267 $S-W=0.748$, $p=0.000$; D: $S-W=0.719$, $p=0.000$). Since the number of cases in each group is only less than 15 in
 268 one case (minimum 13 for female users using aerator D), the results of the ANOVA are still valid. Nevertheless,
 269 the Kruskal-Wallis test also indicates a statistically significant difference on the number of tap pushes for both
 270 female ($H(4)=32.854$, $p=0.000$) and male users ($H(4)=75.999$, $p=0.000$).

271 It was observed that male and female users reacted differently to the discharge reduction. Male users adjusted their
 272 behavior in terms of the number of times the tap is operated in each use to compensate the reduction in water
 273 discharge introduced by the aerators. In practice, this meant that the volume of water per use was reduced by only
 274 about 10% in the interval of discharges between 3.9 and 6.7 l/min and that volume of water per use reduction was
 275 only effective for the aerators with lower discharges. The reduction in water consumption was 22% and 48% for
 276 the aerators with discharges of 3.4 and 2.0 l/min, respectively. Female user behavior, on the other hand, was less
 277 affected by the discharge reduction in the tested interval (2.0 to 6.7 l/min). As a result, the water consumption
 278 reduction was closer to the theoretical water discharge reduction, being higher with female users - between 19 and
 279 50% (Figure 6).

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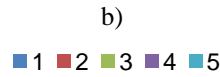
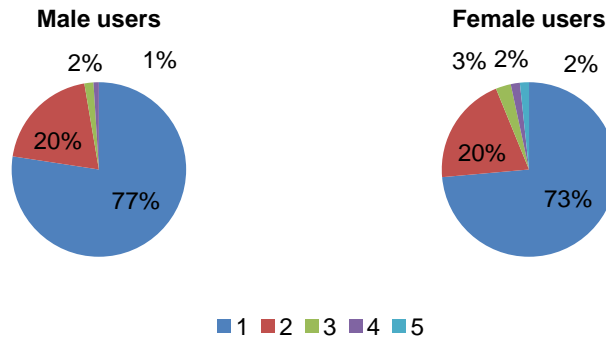


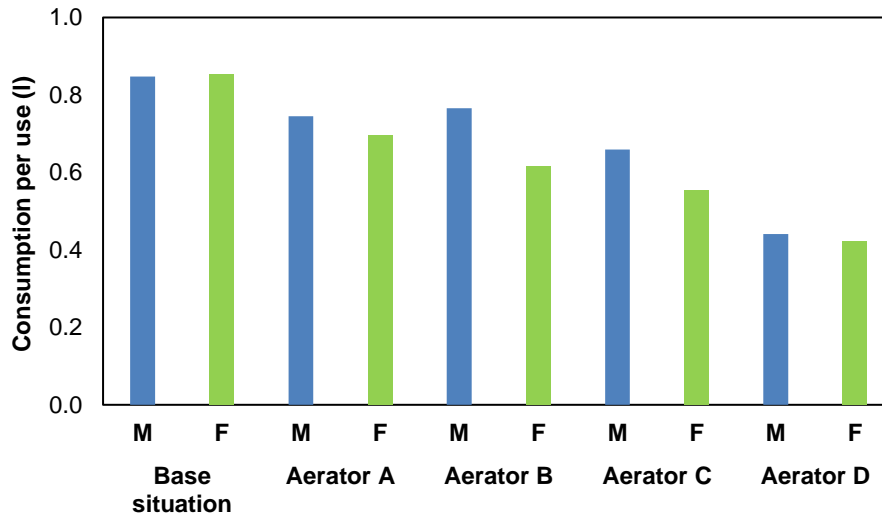
Fig. 4. Number of tap pushes per use for a) male and b) female users



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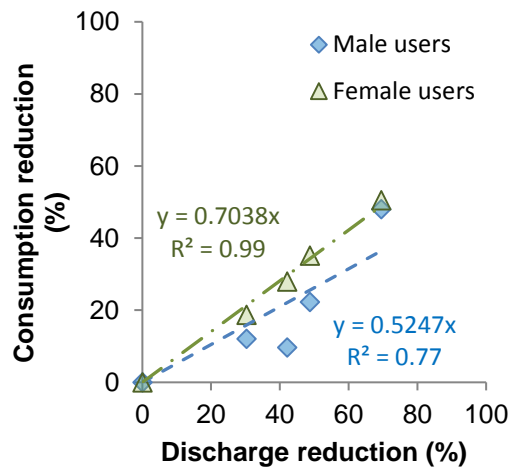
Fig. 5. Number of tap pushes per use for the base situation according to gender

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 ($p=0.076$).



313
 314 Fig. 6. Comparison of the consumed volume of water per use for the base situation and tested aerators, per
 315 gender (M for male users and F for female users)

316
 317 The female users have a fairly linear relation between water consumption reduction and discharge reduction,
 318 whereas male users do not respond linearly to this relation with more distance between direct proportion between
 319 consumption and discharge reduction (Figure 7).



320
 321 Fig. 7. Comparison between discharge reduction and consumption reduction by gender

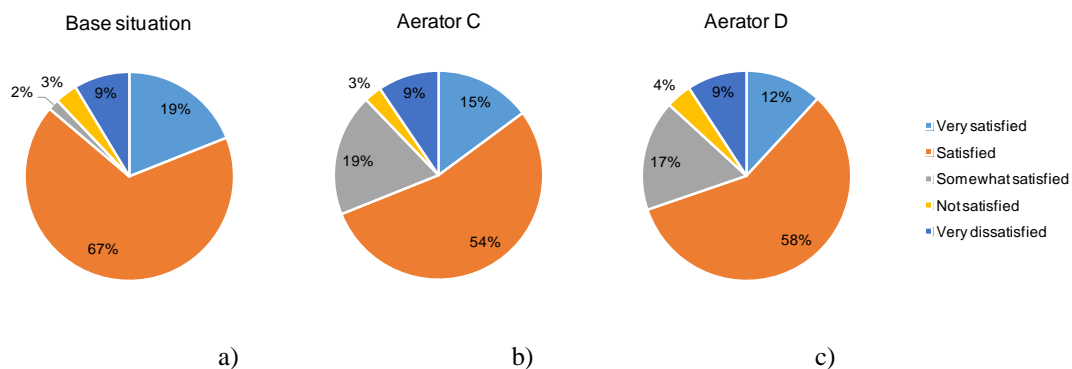
322 It is also interesting to notice that, although female users consumed less water per use with any of the tested
 323 aerators, their consumption for the base situation was fairly equal to the consumption of male users. It should be
 324 noticed that, despite the difference observable in the discharge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

328
 329 **4.3. User preferences**

330 The users were requested to rank their use preference for each aerators in terms using a scale from 1 to 5 (1 - very
 331 dissatisfied; 2 - not satisfied; 3 - somewhat satisfied; 4 - satisfied; 5 - very satisfied) in the direct questionnaires,
 332 which were carried out coincidentally with the installation of the aerators. None of the users classified any of the
 333 aerators as very dissatisfying (classification 1). The exceptions are aerators C and D which some users (less than
 334 10%) considered their use not satisfying (classification 2). On the contrary, more than 45% of the users said that
 335 they were very satisfied about the use of any of the aerators.

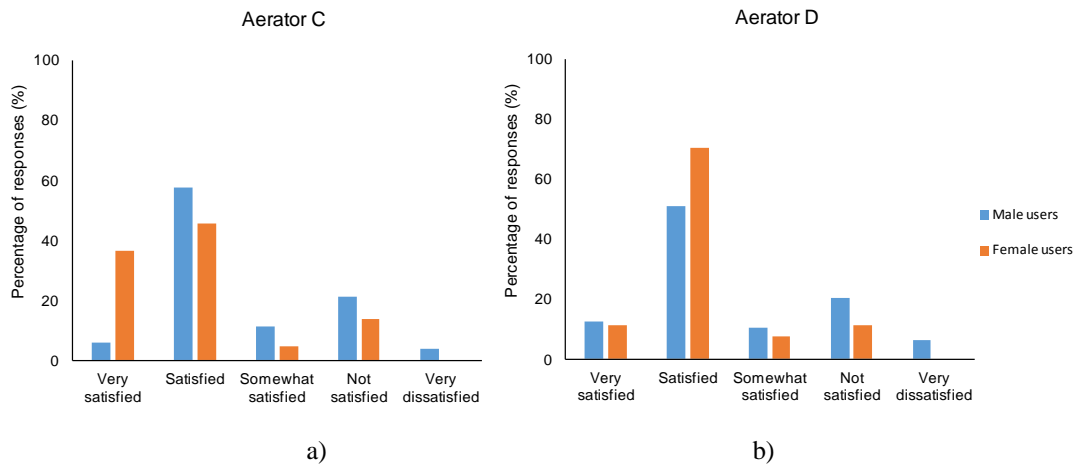
336 In addition, the online questionnaires gauged user preferences after a usage period of at least one week. In the
 337 online questionnaires, the professional position data e.g. undergraduate student, graduate student, researcher,
 338 professor or staff was also obtained. Again, since there was no control over the users replying to each online
 339 questionnaire, the Chi-Squared test was performed to compare the sample of users in each. There were no
 340 statistically significant differences in terms of age ($\chi^2(10)=6.603$, $p=0.762$), professional position ($\chi^2(8)=5.270$,
 341 $p=0.728$) and gender ($\chi^2(2)=0.689$, $p=0.709$) between the samples of users replying to each online questionnaire.
 342 The respondents perception of discharge change and preference results were found to be statistically significant
 343 between the base situation and with aerators (perception: $\chi^2(2)=18.138$, $p=0.000$; preference: $\chi^2(8)=15.852$,
 344 $p=0.045$). Between aerators, the respondents had a statistically weak perception of discharge change ($\chi^2(1)=3.217$,
 345 $p=0.073$) and there was no statistically significant difference on the preference results ($\chi^2(4)=0.601$, $p=0.963$).

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



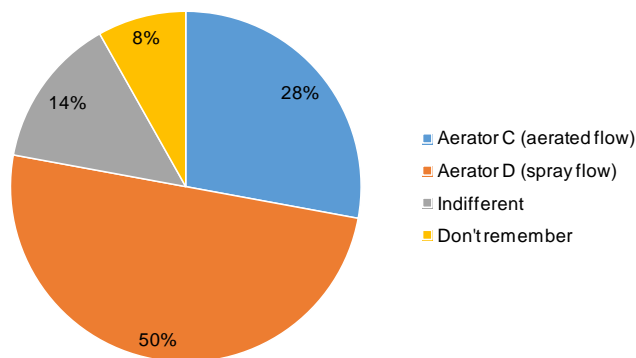
355
 356
 357 Fig. 8. Users preferences: a) base situation; b) aerator C; c) aerator D

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



365
 366
 367 Fig. 9. Users level of satisfaction per gender: a) aerator C; b) aerator D

368
 369 Users were then asked which aerator would serve them better. Around 50% preferred aerator D to aerator C,
 370 against 28% which made aerator C their first choice (Figure 10). These numbers are notable, not only because
 371 aerator D provides a smaller discharge than aerator C, showing that the type of flow is very important for the user
 372 preference, but also because the discharge of aerator D is under the limit of 3-4 l/min recommended by ANQIP
 373 for washbasin taps in general, in order to attain a minimum level of satisfaction.



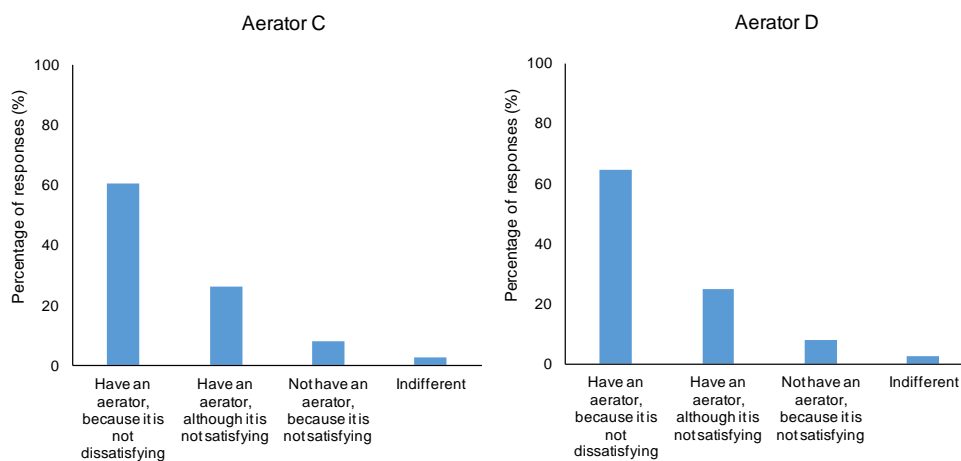
374
 375 Fig. 10. Users choice based on their preferences

376
 377 The Chi-Square test of the preference with the age and professional position of the respondents also resulted in a
 378 $p < 0.1$, but a significant number of the classes of this variables had less than 5 replies, hindering any conclusion.

379

380 4.3. Attitude to saving water

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



387

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

389

390

390 5. CONCLUSION

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

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

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

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

412

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