Effectiveness of water saving devices and educational programs in urban buildings
P. Roccaro, P. P. Falciglia and F. G. A. Vagliasindi

ABSTRACT

In this study different water saving measures (structural and non-structural) were implemented in different urban buildings. A monitoring program of water consumption was carried out to verify and compare the effectiveness of high-efficiency plumbing fixtures and educational programs in different types of buildings (two residential houses, two Middle Schools and two Sport Centres) located in a drought experienced region (Sicily, Italy). In all cases, relevant water conservation percentages were achieved with prominent values in public buildings. The highest water conservation (up to 60%) was observed in two Middle Schools, where a large amount of water was wasted. Overall, the structural measures led to high water conservation, while the educational programs did not always improve the water saving effectiveness. These results highlight that in some urban areas the awareness of water conservation is not well established and large volumes of water are wasted, especially in public buildings, due to faulty plumbing fixtures. Governments and Environmental Agencies should promote with more effort water saving measures in order to support green building policy and global sustainability.

Key words | public buildings, public perception, residential buildings, water conservation, water consumption

INTRODUCTION

Demands on water resources for different purposes are increasing worldwide (U.S. EPA 2004) and, despite the fact that several Mediterranean countries have adequate atmospheric precipitation, water scarcity is often experienced, because of temporal and spatial variations of precipitation (Angelakis & Diamadopoulos 1995; Charalambous 2001; Bonaccorso et al. 2003). Furthermore, climate changes and related extreme weather events could have numerous consequences on a range of environmental, social, and economic sectors, such as water availability and supply (Frederick 1997; Quinn et al. 2001; Arnell & Delaney 2006; Jenerette & Larsen 2006). Due to the lack of specific legislation, many European and Mediterranean countries are identifying appropriate long and short term measures to cope with drought, including supply increase and demand reduction (Andreu et al. 2005; Gikas & Angelakis 2009).

In the field of demand reduction, water conservation may play an important role (Miller 2006). Several studies were carried out to reduce water consumption (Boland 1997; Vickers 2001; Cheng 2003; Syme et al. 2004; Gilg & Barr 2006; Jorgensen et al. 2009). In particular, several water conservation measures could be applied in urban areas, leading to relevant high quality water saving. Such water conservation measures could be broken down into two categories (Di Benedetto et al. 2001): the first include the installation of devices for obtaining water saving and are referred to as structural measures, while the second include the implementation of measures which do not require the application of plumbing products and are referred to as non-structural measures. Furthermore, the structural measures can be broken down into: a) application of flow meters in each building, b) implementation of high-efficiency plumbing fixtures which are simple devices that reduce the water flow (high-efficiency taps, showers, dishwashers and clothes washers, dual-flush toilet technology and hot water recycling systems),

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c) implementation of rainwater recovery systems and/or grey water recycle systems which require capital and operating costs higher than those for the high-efficiency plumbing fixtures. On the other hand, the non-structural measures can be broken down into: managing measures (e.g. restriction of some uses, monitoring and managing distribution systems), economic measures (e.g. economic incentives, pricing) and educational programs for water saving.

In the last decade, many studies concerning wastewater reuse have been focused on public perception, which is often an important barrier for wastewater reuse. These studies have shown that people consider water saving as the most important reason for supporting wastewater reuse. For instance, water conservation is considered a clear benefit of the reuse and the water currently wasted is the largest, least expensive, and most environmentally sound source of water to meet future needs (Friedler et al. 2006; Hartley 2006; Miller 2006). Furthermore, several studies were focused on understanding the technical, social and economic factors that influence the indoor or outdoor water use behaviour. However, the influence of these factors was found to vary widely, even when the same factor was investigated (Gilg & Barr 2006; Jorgensen et al. 2009).

Many water saving measures are well known; however, their application is not well established worldwide and probably people haven’t yet assimilated the awareness of water saving. Although in the recent years some governments have supported the application of water saving measures with incentives for citizens, more efforts are needed in order to reach a sustainable water use. Therefore, the objective of this study is to verify and compare water conservation in residential and public (schools and sport centres) buildings located in Sicily (Italy) implementing high-efficiency plumbing fixtures (structural measures) and educational programs (non-structural measures).

**MATERIALS AND METHODS**

**Buildings investigated**

Several buildings located in Sicily, a drought experienced region (Bonaccorso et al. 2005), were investigated in order to assess the water consumption and the potential of water saving measures. First data on water consumption for different buildings (school, university, barrack, public housing, sport centre, etc.) were acquired and compared with literature data. Then the actual water consumption was measured by means of flow meters in some selected buildings. Finally, two residential buildings (referred to as House A and House B), two sport centres (referred to as Sport Centre A and Sport Centre B), and two Middle Schools (referred as School A and School B) were selected for implementing water saving measures. These buildings having different features (size, type and number of plumbing fixtures, number of users, etc.) were selected in order to compare the effectiveness of water saving measures achieved.

House A has a living area of 110 m² without garden, with one bathrooms, one kitchen without dishwasher, one clothes washer and housed four people during the period of experimentation. On the other hand, House B has a living area of 200 m² with a small garden, two bathrooms, one kitchen without dishwasher, one clothes washer and housed three people (four during the weekend) during the period of experimentation. Both schools have similar numbers of users, but School A has 99 taps and 53 toilets, while School B has 35 taps, 33 toilets and 12 urinals. Sport Centre A is a 350 m² building with two toilets, two taps and four showers and its average number of users was 150 on Monday, Wednesday and Friday and 90 on Tuesday and Thursday, due to different sport activities. Sport Centre B is a 500 m² building with five toilets, seven taps and 14 showers and the number of users was 300 on Monday, Wednesday and Friday and 200 on Tuesday and Thursday.

All the investigated buildings were supplied by a typical urban water pressure provided either by hydrostatic load of the reservoirs posed on the roof or by self-priming pressure boosting pumps installed on the ground floor (these are a widespread water supply system in South Italy Regions).

**Water saving measures applied**

At the selected buildings the water consumption was measured by flow meters before and after the application of water saving measures. The water saving measures applied at the investigated urban buildings in the following experimental phases are summarised in Table 1.

The planning of the experimental phases was aimed at measuring the water consumption before the application of water saving measures, after the implementation of only low-water-flow devices, and after the implementation of both low-water-flow devices and educational programs.
This schedule was chosen in order to verify and compare the effectiveness of different (structural vs. educational) water saving measures applied. It is noteworthy that several low-water-flow devices are nowadays installed in new or restructured buildings and therefore the application of educational programs at the final phase is relevant for the future application.

Therefore, phase 1 of the experimentation was aimed at monitoring the actual daily water consumption at every selected building, before the application of the water saving measures.

At the selected houses phase 2 was conducted after the implementation of both low-water-flow devices (faucets, showers and the dual-flush toilets) and educational programs. This decision was taken because the installation of the low-water-flow devices required the agreement of the users, who wanted to know about it. Therefore, in order to avoid misinterpretation of the water saving results and possible offsetting behaviours (e.g. increasing shower length after installing low-water-flow shower head), it was decided to apply both structural and educational measures in a single phase. However, in order to estimate the weight of the educational programs the water flow of each faucet, shower and toilet flushing was measured before and after the installation of new devices. On the other hand, at both the sport centres and at School B phase 2 was performed after the implementation of only structural water saving measures (faucets and showers), while the following phase 3 included also the implementation of educational programs. Specifically, educational programs were implemented by means of the distribution of brochures showing the water savings tips reported in Table 2. Furthermore, at School A, a questionnaire (not shown) concerning water saving was distributed to the students, and posters showing the water saving tips (Table 2) were placed at the school rooms (e.g. doorways, bathrooms, corridors, gymnasium), in order to provide specific water saving guidelines and to improve the participation of the students.

At School B the educational programs were not implemented, while the structural measures were separated into two subsequent phases (phases 2 and 3) in order to take into account the weight of the replacement of the urinals with new temporised type.

### Table 1 | Experimental phases and related water saving measures applied at the investigated urban buildings

<table>
<thead>
<tr>
<th>Buildings</th>
<th>Experimental phases and related water saving measures applied</th>
</tr>
</thead>
</table>
| House A and House B | Phase 1: monitoring of water consumption before applying water saving measures  
                     | Phase 2: monitoring of water consumption after the implementation of coupled educational measures (brochures showing the water savings tips) and low-water-flow devices (implementation of faucets, showers and the dual-flush toilets) |
| Sport centre A      | Phase 1: monitoring of water consumption before applying water saving measures  
                     | Phase 2: monitoring of water consumption after the implementation of structural measures (low-water-flow devices: faucets, showers and dual-flush toilets)  
                     | Phase 3: monitoring of water consumption after the implementation of structural measures and educational programs (brochures and posters showing the water savings tips) |
| Sport centre B⁺      | Phase 1: monitoring of water consumption before applying water saving measures  
                      | Phase 2: monitoring of water consumption after the implementation of structural measures (low-water-flow devices: faucets and showers)  
                      | Phase 3: monitoring of water consumption after the implementation of structural measures and educational programs (brochures and posters showing the water savings tips) |
| School A⁺           | Phase 1: monitoring of water consumption before applying water saving measures  
                      | Phase 2: monitoring of water consumption after the implementation of structural measures (temporised urinals and faucets)  
                      | Phase 3: monitoring of water consumption after the implementation of structural measures and educational programs |
| School B⁺‡           | Phase 1: monitoring of water consumption before applying water saving measures  
                      | Phase 2: monitoring of water consumption after the implementation of temporised urinals and faucets  
                      | Phase 3: monitoring of water consumption after the implementation of temporised urinals and faucets |

*Dual-flush toilets were not installed at Sport Centre B because flushing stop devices were already present.

At both Schools A and B toilets were not replaced with dual-flush toilets due to agreement issues with local authority.

The educational program was not conducted in School B because no agreement was achieved with the local authority.
RESULTS AND DISCUSSION

Comparison between observed water consumption data and literature values

Table 3 shows the values of water per capita consumption obtained at the investigated buildings before applying water saving measures (experimental Phase 1) and the data from literature. It is noteworthy that the observed water consumption values are in or below the range of those reported in literature. However, a large amount of water was wasted in these buildings, as addressed in the next sections.

Water conservation in residential houses

Figures 1 and 2 show the water consumption trends observed for House A and House B, respectively.

The implementation of simple water saving measures (installation of plumbing products and educational programs) led to a reduction of water consumption from an average of 136 ± 28 to 123 ± 24 litres per capita per day for House A, and from 176 ± 42 to 141 ± 26 litres per capita per day for House B. The average water saving was 9% for House A and 19% for House B.

In both cases a contraction of the standard deviation values of water consumption was observed after the implementation of water saving measures, highlighting that these measures reduce the waste. It is to be highlighted that the installed plumbing products at both houses were not expensive and easy to install and also the educational programs were well received. Moreover, based on the data obtained by the measure of the flow rate of the plumbing fixture before and after the installation of low-water-flow devices it was estimated a potential water saving

Table 2 | Water saving tips reported on brochures and posters for the investigated urban buildings

<table>
<thead>
<tr>
<th>Water saving tips</th>
<th>Houses</th>
<th>Sport centres and schools</th>
</tr>
</thead>
<tbody>
<tr>
<td>Check all plumbing for leaks and make necessary repairs or inform the owner for repairs</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Install low-flow faucets and shower heads</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Reduce toilet flushes or install dual-flush toilets</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Don’t use the toilet as wastebasket</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Use a shower rather than bath</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Reduce the number of baths/showers</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Take only few minutes showers</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Turn off tap when brushing your teeth or making your shave or soaping up</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Turn off tap when washing dishes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Install a water-efficient clothes washer and use it for full load only</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Install a water- and energy-efficient dishwasher and run it only at full load</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Wash the car with a bucket and a sponge rather than using a continuous water flow</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Collect and use the rainwater</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Use plants that need less water</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Use a sprinkler less in the garden or adopt sub-irrigation systems</td>
<td>Yes</td>
<td>No</td>
</tr>
</tbody>
</table>

Table 3 | Comparison between observed water consumption values at the investigated buildings during experimental phase 1 (before applying water saving measures) and literature values

<table>
<thead>
<tr>
<th>Building</th>
<th>Daily water consumption (L/d)</th>
<th>Average users per day</th>
<th>Observed average water consumption (phase 1) (L/person d)</th>
<th>Range of water consumption from Milano (1996) (L/person d)</th>
<th>Range of water consumption from Metcalf &amp; Eddy (2003) (L/person d)</th>
</tr>
</thead>
<tbody>
<tr>
<td>House A</td>
<td>544</td>
<td>4.0</td>
<td>136</td>
<td>150–250</td>
<td>150–390</td>
</tr>
<tr>
<td>House B</td>
<td>581</td>
<td>3.3</td>
<td>176</td>
<td>150–250</td>
<td>150–390</td>
</tr>
<tr>
<td>Sport centre A</td>
<td>1,569</td>
<td>123</td>
<td>13</td>
<td>30–40</td>
<td>55–110</td>
</tr>
<tr>
<td>Sport centre B</td>
<td>7,720</td>
<td>255</td>
<td>30</td>
<td>30–40</td>
<td>55–110</td>
</tr>
<tr>
<td>School A</td>
<td>18,500†</td>
<td>700</td>
<td>26</td>
<td>20–90</td>
<td>40–80</td>
</tr>
<tr>
<td>School B</td>
<td>13,800†</td>
<td>800</td>
<td>17</td>
<td>20–90</td>
<td>40–80</td>
</tr>
</tbody>
</table>

†Values for population from 5,000 to 50,000.
‡Data showed are obtained from working days.
was attainable of 12% for House A and of 35% for House B. These estimated percentages vary with the different indoor water usage and with the flow rate of the plumbing fixture originally present. In agreement with the estimated potential water saving achievable, higher water conservation was observed at House B. Furthermore, obtained water saving shows that the educational measures had a negligible additional effect at both houses.

**Water conservation in sport centres**

Water conservation achieved in both sport centres was analysed distinguishing each working day, because different numbers of users were observed during different days of the week. High percentages of water were saved in both sport centres after the implementation of structural measures (Figures 3 and 4). In particular, more than 21% and 40% of water conservation was observed in Sport Centres A and B, respectively. The implementation of educational programs did not always improve water conservation (Figures 3 and 4). Overall, the obtained water saving after the implementation of educational programs (phase 3) agrees with the observed response of the users. Indeed, while the educational program was well received from the users at the Sport Centre A, the users of the Sport Centre B were very upset about the proposed water saving tips and they did not want to change their behaviour (Parisi et al. 2004). A possible offsetting behaviour of some users may be the reason for the negligible or
February 1st to February 8th high water consumption was observed on both working and non-working days. High water consumption in both schools was measured daily during working and non-working days. High water consumption was observed on both working and non-working days before the implementation of water saving measures, as shown in Figures 5 and 6 for School A and School B, respectively. The latter result is notable, especially in School B, where, for example, during the days from February 1st to February 8th high water consumption was observed. This water wasted could be due to some taps left open by students.

The implementation of water saving measures led to a relevant water conservation in both schools, even higher than in residential buildings (Houses A and B). This result is in agreement with a previous study that has highlighted that most primary schools might have problems of consuming too much water, involving leaking pipes, or faulty water facilities (Cheng & Hong 2004).

The effectiveness of structural measures was very high at School A where a very low amount of water consumption was observed during the non-working days (Figure 5), highlighting that these measures could minimise the leaks in public buildings where a lot of users are present with little attention for water spilling (e.g. taps not well closed). Furthermore, a strong reduction of water consumption was also found on working days, with 60% of average water conservation achieved during the second phase of the experimentation (only structural measures applied), when no peak of water consumption was observed. By contrast, a negligible additional effect of non-structural measures was observed (phase 3). This could be due to a very low interest of users (children aged between 10 to 13 years) for water saving measures. Indeed, in some case students removed or damaged the posters placed inside the school, and only about 14% of questionnaires were compiled, even though a sufficient knowledge of the students about the water saving education reduction. On the other hand, it is noteworthy that water saving obtained after the implementation of educational programs at school varies a lot and it is very difficult to be quantified (Texas Water Development Board 2004).

Overall, the negligible water saving obtained in this study through the educational program agrees with previous studies (Glig & Barr 2006) showing that only some non-structural measures such as price and economic incentives strongly influence the behaviour of water users and that educational programs are successful only if a personal sacrifice, a reduction in comfort or a significant change of
the behaviour is not required. Therefore, if a significant water saving is achieved by means of structural measures, it will be very difficult to obtain a further saving through educational programs.

Water consumption was also reduced after the implementation of structural measures at School B (Figure 6). Although also in this case a large amount of water was saved (average value of 50%), some peaks of water consumption were still observed after the implementation of water saving measures, possibly due to the outdoor usage of water for the irrigation of the garden. However, since also the water consumption on non-working days was not well minimised, it was speculated that some leaking pipes could be present in the building. At the School B the more effective structural measure was the replacement of urinals as shown in Figure 6, because a very low additional reduction of water consumption was observed during phase 3, compared with phase 2.
Since in both schools water consumption values before the implementation of water saving measures were lower or in the range of literature values (Table 3) during the working days, only a deeper investigation of water consumption, also implementing water saving measures, has demonstrated that a large amount of water was wasted.

CONCLUSIONS

Results obtained in this study show that the expected water consumption (litres per capita per day) based on literature data is not always a good indicator of the correct water usage and only deeper investigation can give information about wasted waters, especially in the case of public buildings.

The application of structural water saving measures can be very useful for controlling both water consumption and spillings in either residential or public buildings, with the more prominent conservation in the public buildings. Overall, the installation of simple plumbing products can result in a percentage of water saved from 10% to 20% in residential buildings and from 25% to 60% in public buildings. The higher water conservation observed in public buildings is probably related to the specific water usage that includes the use of taps, toilets and in some cases showers, while the more broad residential usage results in lower water conservation. For instance, relevant spills may occur in public buildings that can be reduced by using simple temporised or infrared low-water-flow devices.

Another important result is that educational programs may have a negligible additional effect in either residential or public buildings. Indeed, in this study some water users, including children, ignored the proposed water saving tips and they did not change their behaviour. Furthermore, a possible offsetting behaviour of some users may be the reason for the negligible or negative effect of the implementation of the educational program on water saving. The fact that the concept of water conservation is only marginally adopted by children is a strong indicator of the low awareness and education of the society with respect to water usage. The fact that this happens in a region with experienced drought conditions is of concern.

This study also highlights that the application of structural water saving measures (i.e. low-water-flow devices) can minimise the possibility of wasting the water, making difficult a further water consumption reduction through the implementation of educational programs.

Overall, it can be concluded that in some urban areas the awareness of water conservation is not well established. Large water volumes are still wasted in some buildings where conventional taps, toilets and showers are present. Therefore, it is suggested that Governments and Environmental Agencies would make more effort to provide funding to promote water use efficiency and conservation.

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REFERENCES

Gikas, P. & Angelakis, A. N. 2009 Water resources management in Crete and in the Aegean Islands, with emphasis on the


Victorian Government Department of Sustainability and Environment of Melbourne 2007 *SWEP (School Water Efficiency Program) final report*. 