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A Case Study of Flow Regulators Installed in Washroom Taps within an Office Building

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Authors' contributions

This work was carried out in collaboration between all authors. Author SRB designed the study and wrote and revised the manuscript. Author JC provided research advice and revisions to the manuscript. Author SB financially managed the project and liaised with relevant BRE departments and staff. Authors LH and SRB undertook the data analysis. Author MH offered occupant behavioral insights and commented on the manuscript. All authors read and approved the final manuscript.

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Case Study

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ABSTRACT

Aim: To evaluate the operational performance of water efficiency products in order to report the actual-versus-potential impact on water demand.
Study Design: The study monitored the volume of water used from taps situated in two male and two female washrooms in an office building. During a 21 week period, the tap flow rates were decreased, without occupants being informed, and water usage was recorded and analysed.
Place and Duration of Study: The first floor of an office building located at the Building Research Establishment (BRE) site, in Garston near Watford, UK. The study took place from December 2012 to May 2013.
Methodology: Flow regulators were installed in-line with the taps to reduce the flow rate. Using flow meters and data loggers, the water usage was recorded and analysed.
Results: During the 21 week study, 6,217 events were recorded, where an event consisted of one or both taps being used in the same visit by a single user. The installation of the flow regulators failed to provide robust evidence that a reduction in water flow from taps equated to an increase in water efficiency.
Conclusion: Evaluating the operational effectiveness of low cost water efficiency products is time consuming and expensive. The actual performance of flow regulators, which are low cost and simple to install, failed to achieve the expected gains in water efficiency.

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1. INTRODUCTION

In the operation of a non-residential building the water supply costs are marginal, relative to the other utility costs. The low cost of water reduces the level of priority that organisations place on water efficiency. However, government policy in the UK and EU (and elsewhere) supports reducing water consumption due to the environmental benefits of reduced consumption both in terms of energy savings and reduced impacts on water supply sources. Businesses judge the financial value of water efficiency measures based on the financial payback period – how quickly the capital cost of a product is repaid through efficiency gains. Whilst the payback period focuses mainly on financial cost, the environmental value of water can be accounted for through an organisation's corporate social responsibility policy and so, despite a weak economic case for investment, businesses may sometimes choose to invest in water efficiency measures.

The aim of this study is to evaluate the operational performance of a water efficiency product in order to report the actual-versus-expected reduction in water demand. Performance monitoring is advantageous as it provides feedback to the user on the validity of product assumptions, helps identify any unintended consequences and provides insight into user behaviour. However in instances where water efficiency measures are of low financial cost, it is argued that performance monitoring is not widely undertaken. Research was undertaken on the effectiveness of using flow regulators [1] to reduce the water consumption from taps. The study selected a flow regulator as an example of a water efficiency product which is low cost, simple to install and without ongoing maintenance requirements.

This research study (Study) was conducted in an office building, referred to henceforth as the Case Study Building. The building is located at Building Research Establishment (BRE) in Garston, near Watford. The flow regulators were placed inside the individual water supply isolation valve installed in-line with the water supply to the taps. Water supply to the taps was regulated using either a 6.0 litre per minute (lpm) or 4.0 lpm flow regulators.

1.1 Background

Increased demand on water supplies has resulted in regional water stress in the UK [1]. The increase in water demand is attributed to populations growing, people moving to densely populated areas, and precipitation patterns changing. The Met Office predicts the UK will experience 'wetter winters and drier summers', with worst case analysis warning of a ten-fold increase in significant[2] droughts by 2080 [2].

There are three water efficiency drivers that were identified: mandatory requirements; best-practice guidance and financial incentives. Mandatory requirements include UK Building Regulations [3], Water Supply (Water Fittings) Regulations 1999 [4], and the Water Act 2012 [5]. In addition, the Office of Water services (OFWAT) requires water companies to reduce customer water use year-on-year [6]. Although not strictly a regulatory requirement, building environmental assessment methods, such as BREEAM and LEED, encourage water efficiency as part of the final environmental rating of building [7,8]. However, in some circumstances a building is required to achieve a prescribed environmental rating in order to discharge a planning requirement and/or obtain project funding [9]; therefore an environmental rating becomes a mandatory requirement. Best practice guidance for building operators is available from various industry and government supported schemes, many of which provide free on-line training modules and case-study examples of water efficiency [10–12]. Additionally, helped by the EU water label, people who buy sanitary fittings are more readily informed of the potential water efficiency of the products. Implementing water efficiency is also financially incentivised via Her Majesty's Revenue and Customs (HMRC) enhanced capital allowance scheme which allows businesses to reduce tax paid on water efficiency products [13]. These three drivers provide numerous resources to encourage water efficiency. However in order for water efficiency measures to be adopted by businesses, the potential water demand reduction needs to be calculated.

[1] *Flow Regulators manufactured by http://www.neoperl.net/*

2 The Met Offices used the 1975-1976 drought to illustrate the meaning of a 'Significant' drought.

There are a number of robust methods reported in academic literature which have been demonstrated to accurately predict water demand and potential water efficiency gains in buildings. The approaches used in these models include a stochastic-based approach, where there is less reliance on assumptions of water use and duration [14]. Also site-specific mass-flow calculations which rely on measurements of water input and output to the building and graphical representation to identify areas of water efficiency gain [15–17]. Additionally, pulsed output data from water meters can be analysed to identify patterns of water flow based on water flow rate and duration to identify the likely end uses [18]. However, because these models are not widely known or accessible to a typical building manager, the model advantages are not fully exploited. Instead a strong reliance remains on calculating water demand using a deterministic approach.

The deterministic approach is based on three input assumptions multiplied together to calculate the water demand for individual sanitary fittings. These assumptions are the frequency of use, the flow rate and the duration or capacity of use. This method is then repeated for all sanitary fittings within a building to calculate total building water demand [19–21]. This calculation approach is promoted in best-practice guidance, such as the Calculating Domestic Water Use in Non-Domestic Buildings publication [20]. A limitation of the accuracy of the deterministic approach is the evidence base used to populate the input assumption data [22,23]. Arguably, the most widely used assumptions, as demonstrated by inclusion in work by the Market Transformation Programme [24] and British Standard guidance [20], were originally based on research by the Water Research Council in 2005 [25]. However, these assumptions were based on research from 400 houses, as opposed to non-household buildings. Furthermore, with respect to the volumetric demand of individual sanitary fittings, in 2008 the Market Transformation Programme estimated that total water consumption by products with reliable data was equivalent to 20% of domestic water supplied [26]. In summary, it is argued that the deterministic method of calculating water demand is overly reliant on less than robust assumptions regarding frequency and duration of use for water fittings. The deterministic method is endorsed by British Standards in their Code of Practice for calculating water demand [20]. This endorsement is likely to result in users selecting the deterministic method instead of alternative, more sophisticated, and robust methods to calculate water demand.

A key challenge in improving the assumptions used, for duration and frequency of use, relates to data collection methods prohibited by privacy rights. Historically data has been obtained using intrusive methods for recording washroom behaviour such as: Researchers standing in washroom areas and noting frequency and duration of use [27] and, the use of sensor and recording equipment to monitor washroom behaviour [28,29]. However, this type of intrusive research can be problematic due to privacy rights etc. Accordingly, data collection is now more focussed on the use of water metering equipment and data analysis to test the in-use effectiveness of water efficiency products installed in buildings.

An alternative, less intrusive, method of calculating water efficiency savings analyses water meter data before-and-after the installation of a water efficiency product, and a differential water demand is then attributed to the product. However, this method is reliant on the product being directly metered. Alternatively a water efficiency product is installed on the dominant water fitting, and water demand readings are taken from a sub-meter, measuring several sanitary fittings. However, this method of before-and-after installation measurement is undermined by variance in occupancy use, behavioural patterns and hours of operation [30].

The effectiveness of a water efficiency product has also been widely evaluated by comparison with a control group that does not have a product installed. The type of product effectiveness test is widely used in research by numerous water supply companies [31]. One drawback of this method is that all buildings in the studies should have very similar occupancy characteristics. This method has also been shown to be less effective when applied to non-residential buildings, due to the variability in building functionality [31].

In 2010 a report titled ‘Evidence Base for Large Scale Water Efficiency’ [32], published the results of a large-scale evidence base focussed on water efficiency in 600 schools. The effectiveness of the products in this large scale study were evaluated using a before-and-after comparison of water demand. The total water demand was disaggregated into individual products, such as taps and toilets, in order to evaluate the volume of water used by different sanitary fittings.

However, a key weakness of this approach was its adoption of the deterministic approach, previously outlined, which relied on potentially flawed assumptions, specifically when comparing hypothetical reduction in water demand with actual water meter data. A further challenge in this before-and-after approach relates to potential water leakage which can skew the results considerably.

It has been shown that the existing data used to calculate water demand is heavily based on assumptions of duration and frequency of water use. Analysis of before-and-after data, and control groups do offer a strong indication of potential achieved water savings but due to numerous variables, occupancy rate etc., the results are less robust. An alternative approach to quantifying water efficiency savings is the use of micro-scale measurements, as used in this study. In micro-scale measurements the flow meters and data loggers are directly connected to, and only to, specific water efficiency products in order to test the effectiveness of a product. In this study, a case-study example is reported to show how micro-scale measurement can be undertaken, the results achieved and the barriers of measuring individual products are identified.

2. METHODOLOGY

Hot water in the case study building is supplied to the taps by a pumped flow-and-return system which continuously circulates hot water. Cold water is gravity fed to the taps from a header tank located on the roof of the building. Water is supplied to the taps at 1.5 bar pressure. The study focussed on two male and two female individual washrooms. Each washroom contained a toilet and a hand basin with individual hot and cold taps. The tap design, known commonly as pillar taps, require the user to loosen or tighten the dome-shaped tap handle to control the flow of water from the tap.

2.1 Data Collection Method

The objective of the methodology was to test the effectiveness of flow regulators, which were installed to limit the flow rate from the taps. To measure the volume of water discharged from the taps, individual flow meters were installed in-line with the supply pipe to each of the eight taps. The flow meters[3] supplied a pulsed output via sensor cable to a multiple input data logger[4] situated in an adjacent room. When a tap was opened, the flow meter sent a series of pulses to the data logger. Each pulse represented a unit of water, termed the K-factor. The volumetric water usage was calculated using the number of pulses received by the data logger whilst the tap was being used. The K-factor for each flow meter was regularly tested during the study to ensure consistent data output. The testing involved filling a one litre water container from each tap and comparing the number of pulsed outputs, recorded by the data logger, with previous tests.

The volume of water drawn from a tap, in this study, is defined as an ‘event’. A single event, measured in litres, is said to occur when one or both taps in a washrooms is used. Data recorded from one or both taps used concurrently and within a 60 second time frame was analysed as one event. Following discussion with building occupants, who stated washrooms queues were unusual, the study assumed that taps operated within 60 seconds of one another were likely to be attributed to the original user as opposed to a new user who had been queuing outside.

The flow regulators used in this study were designed to limit the maximum tap flow rate to either 6 lpm or 4 lpm. However the study lacked tap specification to show how far the tap needed to be turned on in order to achieve maximum flow rate. This relationship was considered to be an important factor when evaluating the effectiveness of the flow regulators in the taps. Accordingly, the study conducted in-situ testing on each tap to plot this relationship. Data was obtained for each tap using the following procedure: A plastic disc with a hole in the centre was fabricated and marked with 20 degree increments. The disc was located on the tap spindle underneath the tap head. With the data logger recording the pulsed output from the tap flow rate, the tap was open incrementally every 10 seconds in 20 degree steps until the tap was fully open. This process produced a plot, Figs. 1 and 2, of flow rate versus tap rotation and which clearly indicated how far the tap had to be turned to reach maximum flow rate.

Data from the Study was analysed using Microsoft Excel and statistical software, SPSS. Data was download every third day. The data was processed frequently to monitor the

[3] *Flow meter specification available from: http://www.flowmeters.co.uk/pdf/turbine_meters/800_series/800-series-data-sheet.pdf*

[4] *Eltek data logger specification available from: http://www.eltekdataloggers.co.uk*

functionality of the equipment and to check the methodology objective was being achieved. To reduce the risk of human error when data processing, a macro for Excel was written to automate the data process. In addition to the automated processing, manual calculation checks confirmed the data was being correctly processed.

2.2 Research Design

The study duration was 21 weeks (105 business days) and was conducted from 6th December 2012 to 5th May 2013. The three stages of the study are shown in Table 1 and were as follows: establishing baseline water consumption, and then reduction of tap flow rate in two stages. Data monitoring was only carried out on business days, as during the weekend the building is largely unoccupied.

3. RESULTS

Table 2 shows the total volumetric demand from the hot and cold taps in the four washrooms, with results disaggregated into male and female washrooms. The sample size from male versus female washrooms is relatively equal, with just 5% more events recorded in male washrooms. The data shows the building occupants use the hot tap more frequently than the cold. In the male cubicles, the ratio of hot tap versus cold tap usage is 3.9 versus a 2.2 hot tap to cold tap ratio in the female washrooms.

Figs. 1 and 2 show the graph plot of hot and cold flow rate versus how far the taps are turned. A similar trend is seen in both figures – the flow rate quickly increases and then plateaus. The difference in results relates to how far the taps need to be opened to achieve a maximum flow rate. When there is not a flow regulator installed in the hot and cold taps, the maximum flow is achieved by turning the taps on approximately three-quarters of a full turn, 270 degrees. However, when either a 6.0 or 4.0 lpm flow regulator is installed the taps only need about a third of full turn, 120 degrees, to reach maximum flow rate. The profile of all three flow rates is shown to be largely unaffected by the presence of a flow regulator when the taps are turned on a quarter turn.

The results shown in Figs. 1 and 2 also highlight that the actual maximum flow rate were less than the anticipated 6.0 lpm and 4.0 lpm as assumed from the flow regulator specification. The in-use flow rates are shown on Table 3. The low standard deviation value indicated that a consistent flow rate from the taps was experienced.

Table 1. Number of days of data collection for each change in tap flow rate

Stage	Intervention	N° days*	Start	End
1	Baseline data collection: 9.0 lpm tap	30	06/12/12	14/01/13
2	6.0 lpm flow regulator installed	37	18/02/13	26/03/13
3	4.0 lpm flow regulator installed	38	27/03/13	03/05/13
	Total number of days	105		

** The number of days excludes weekends and bank holidays*

Table 2. Total tap water demand during study period from hot and cold taps in the male and female washrooms

Summary:	n	Volume (^{m3})
Cubicle one male + cubicle two male: Cold tap	668	0.47
Cubicle one male + cubicle two male: Hot tap	2,594	1.20
Total: Males	3,262	1.68
Cubicle one female + cubicle two female: Cold tap	924	0.58
Cubicle one female + cubicle two female: Hot tap	2,031	1.24
Total: Females	2,955	1.82
Total: Males + Females	6,217	3.50

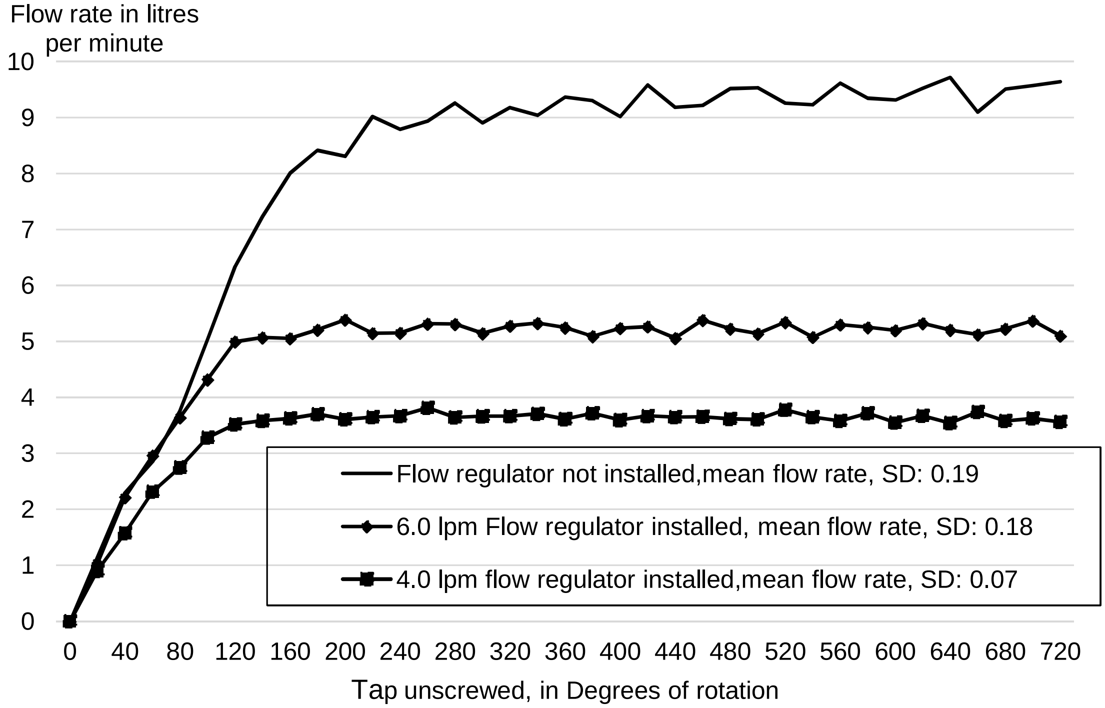

Fig. 1. Hot tap mean flow rate relative to the rotation, in degrees, the tap is opened to increase flow rate

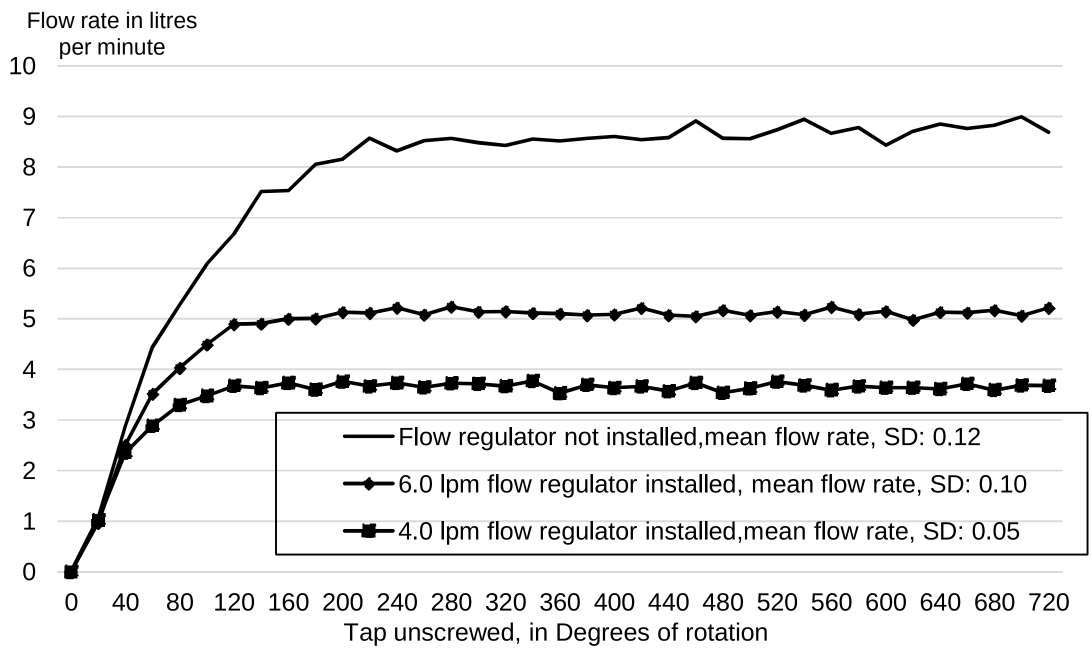

Fig. 2. Cold tap mean flow rate relative to the rotation, in degrees, the tap is opened to increase flow rate

The main intent of installing flow regulators is to make the taps more water efficient by reducing the flow rate. However, as shown in Tables 4 and 5 Water demand per event decreased in the male washrooms, conversely the opposite effect was recorded from the female washrooms. A minor exception to this increase in water demand is noted from the cold tap in the female washroom number 3. Overall, the results demonstrate that the installation of flow regulators were consistently more effective at reducing the volume of water used per event in the male versus female washrooms. However, the flow regulators failed to consistently and reliably reduce water use from all taps included in the study.

4. DISCUSSION

This research project is an example of water monitoring at a micro-level and which provided highly granulated data. Water metering on a whole building scale or even on individual floors is unlikely to provide the necessary granularity of data required to monitor sanitary fittings with variable flow rates and consumption, such as taps and as opposed to toilets cisterns. The data collection methodology provided a reliable means of measuring and recording the events.

The area within the case study building where the study took place was ideally suited for monitoring. The close proximity between the data logger and flow meters made routing the sensor cable inside the wall cavity straightforward. Also, ensuring the data logger was located in an adjacent secure room provided reassurance that equipment would not be tampered with or removed. If the study were to be replicated in a different building, researchers would be advised to give early consideration to the practicalities of data monitoring. For example, the data logger required a power input, sensor cables are a potential trip hazard if not safely routed, and ‘hiding’ equipment from inquisitive people is desirable. These challenges are surmountable but in the context of a washroom such constraints are magnified by the potential for water egress into the equipment and an absence of power points in UK washrooms. Notwithstanding, sensor cables can be replaced by wireless data communication, assuming reliable connectivity is available.

From the perspective of a facilities manager for a non-household building, the level of measurement undertaken in this study is cost and time prohibitive. The low cost of water is disproportionate to the high equipment purchase and installation costs of the monitoring equipment. The facility manager would need to reconcile and justify the benefits of such a study against the benefits of such detailed measurements. If a facilities manager was responsible for many similar building types, with comparable functionality, working practises and sanitary fitting, replicating the study would be useful. The study would help a facilities manager make an informed decision as whether installing flow regulators would improve water efficiency. Conversely, a facilities manager responsible for one or two buildings is unlikely to be able to justify a study similar to this one. Accordingly, the decision to monitor or to rely on assumptions of water efficiency savings becomes another cost-benefit decision at a facility manager scale. However, taking a more holistic view, the study has clearly demonstrated that the importance of checking assumptions regarding the effectiveness of water efficiency products in different contexts.

A significant challenge encountered in the study related to data analysis. Without observing occupants using the taps it is very difficult to correlate and compare the effectiveness of the flow regulators with how occupants are using the taps. In this research project it has been broadly assumed that occupants are washing their hands but this assumption was not validated by observation. Occupants potentially perform a gamut of activities which use water, such as cleaning their teeth, washing fruit, or cleansing before prayers.

Table 3. Maximum tap flow rate, with and without flow regulator installed

Assumed max. flow rate (lpm)	Hot tap actual flow rate (lpm)	N	Standard deviation	Cold tap actual flow rate (lpm)	n	Standard deviation
9.00	9.40	76	0.14	8.70	76	0.12
Flow regulator installed: 6.00	5.22	76	0.06	5.12	76	0.05
Flow regulator installed: 4.00	3.64	76	0.03	3.65	76	0.03

Table 4. Water use per event, in the male Cubicles, in relation to flow regulators installed and the percentage change relative to the original flow rate without a flow regulator installed

Description	Flow regulator installed	Mean (lpe)	% change relative to 9.00 lpm	n	Volume (l)	SD	Maximum (lpe)
Washroom 1 male	NA	0.85	0.00%	143	121.55	1.39	14.42
Cold tap	6.00	0.68	**-(20.00)%**	179	121.72	0.74	3.39
	4.00	0.49	**-(42.35)%**	47	23.03	0.40	1.52
Cubicle 1 male	NA	0.42	0.00%	505	212.10	0.62	8.03
Hot tap	6.00	0.39	**-(7.14)%**	650	253.50	0.61	11.27
	4.00	0.32	**-(23.81)%**	277	88.64	0.44	4.65
Washroom 2 male	NA	0.79	0.00%	91	71.89	0.90	6.12
Cold tap	6.00	0.69	**-(12.66)%**	164	113.16	1.20	14.31
	4.00	0.50	**-(36.71)%**	44	22.00	0.56	2.22
Washroom 2 male	NA	0.57	0.00%	297	169.29	0.78	10.18
Hot tap	6.00	0.49	**-(14.04)%**	408	199.92	0.52	5.36
	4.00	0.47	**-(17.54)%**	158	74.26	0.66	5.43

Table 5. Water use per event, in the female washrooms, in relation to flow regulators installed and the percentage change relative to the original flow rate without a flow regulator installed

Description	Flow regulator installed	Mean (lpe)	% change relative to 9.00 lpm	N	Volume (l)	SD	Maximum (lpe)
Washroom 3 female	NA	0.57	0.00%	148	84.23	1.09	6.71
Cold tap	6.00	0.55	**-(3.51)%**	236	130.83	0.79	4.95
	4.00	0.54	**-(5.26)%**	72	38.89	0.88	4.91
Washroom 3 female	NA	0.59	0.00%	357	210.00	0.73	8.19
Hot tap	6.00	0.64	8.47%	521	335.06	0.70	7.09
	4.00	0.65	10.17%	187	121.74	0.79	5.47
Washroom 4 female	NA	0.57	0.00%	196	112.38	0.83	4.94
Cold tap	6.00	0.75	31.58%	188	140.74	1.06	6.78
	4.00	0.85	49.12%	84	71.40	1.33	6.94
Washroom 4 female	NA	0.56	0.00%	336	186.85	0.46	4.11
Hot tap	6.00	0.59	5.36%	465	275.53	0.50	3.96
	4.00	0.69	23.21%	165	114.18	0.69	4.26

The results report that building occupants use the hot taps more often than the cold taps. This could be attributed to a number of explanations. Firstly, occupants may simply have a preference for hot water use based on rationale such as: Hot water is perhaps more comfortable to use, particularly in colder weather; a belief that hot water is more effective and hygienic for hand washing, or the temperature of the cold tap, for some people, is to low and unpleasant for handwashing. An additional explanation relates to user convenience. Occupants may feel that using one tap is more convenient than operating separate taps. Finally, it is feasible to suggest that washing both hands under a single stream of water is more logical to occupants. Further research is needed to explore these potential explanations. However the results suggest that a focus on reducing hot water usage, without diminishing occupant user satisfaction, is likely to provide a larger reduction in water demand.

In this study, flow regulators were used to help reduce water demand. However, the research demonstrated the relative effectiveness of the flow regulators at reducing water demand is dependent on how far the tap is opened, as shown by Figs. 1 and 2. During the early stage of opening the tap, the flow rate is similar under all three conditions: flow regulator not installed, and 6.0 lpm and 4.0 lpm flow regulators installed. It is only when the taps are unscrewed to around 40 degrees, that any difference in flow rate is evident. When the tap is further unscrewed to 120 degrees a distinct and uniform flow rate emerges. Accordingly, reducing the tap flow rate using flow regulators has been shown to only be effective when occupants rotate the tap at least 120 degrees.

The study did not record how far the taps were opened by the occupants. The results suggest that occupants do not open the taps enough for the effectiveness of the flow regulator to be realised. This tentative assertion could be tested by modifying the tap to achieve full flow within a shorter tap rotation, and the study repeated. An alternative method would physically measure how far the taps were turned by occupants. The latter approach would be preferential as results would provide an insight and contribution to knowledge into tap usage behaviour.

The monitoring equipment was configured to record the number of pulses over a 60 second duration, as opposed to the number of pulses every second. Monitoring the number of pulses every second would have recorded, for each event, the duration of tap usage. Setting the data logger to record every second was trialled in the early stages of the study, however it was found that the logger memory was exceeded within 2-3 hours. This meant that the data would need to be downloaded around 3-4 times per day for the duration of the study. It took 1 hour, on average, to download the data including transferring the data to a master database. The work load of the research team meant that spending 3 hours each day on this task was overly time intensive and not practical.

Figs. 1 and 2 highlight the importance of testing assumptions with respect to water efficiency interventions. The data shows that the 6.0 lpm and 4.0 lpm flow regulators limit the flow rate less than the anticipated flow rates. In terms of water efficiency, lower flow rates maybe be beneficial. However, user satisfaction is critical to promote water efficiency and the potential exists for users to become dissatisfied with a flow rate believing the flow rate to be a 6.00 lpm or 4.00 lpm. Equally, if assumptions are not tested and the flow rate is greater there is the potential for a false assumption that water demand has been reduced.

It is important to note that the mean water use per event has a high standard deviation. In addition, on occasions, the water use per event was very high. The data shown in Tables 4 and 5 suggest that the water use per event decreased in the male washrooms, but conversely, water use increased in female washrooms. Due to the high standard deviation observed, the results cannot conclusively report the effectiveness of flow regulators and if there is a difference in efficiency which can be attributable to the gender of the tap user. However, the research can claim to show the necessity of validating the effectiveness of water efficiency products at the point of use.

5. CONCLUSION

The importance of water efficiency is becoming widely accepted. It is encouraging that this message is now broadly supported by both the private and public sector. However, the majority of the existing building stock do not promote water efficiency. Recently constructed sustainable buildings with low flow sanitary fittings, water reuse systems and automatic meter reading technology encourage greater water efficiency compared to older building stock. However, there is a gap between potential and actual water efficiency.

The aim of this study was to evaluate the actual operational performance of a water efficiency product. The type of water efficiency product, a flow regulator, in this study were chosen as it is low and simple to install. Such products are appealing to facilities managers who are tasked with ensuring buildings remain operational whilst attempting to reduce operational costs. Accordingly, it is argued, for facility managers, products such as flow regulators are a ‘low-hanging fruit’ when investigating water efficiency options for buildings.

The predominant finding was that the installation of the flow regulators did not result in a consistent and predictable decrease in water use per event, although overall water use in the male washrooms decreased when flow regulators were installed. Prior to beginning the research it was anticipated that installing the flow regulators would provide an incremental decrease in tap water usage per event. The data gathered suggests that in the male washrooms the water use per event did decrease overall. However the opposite effect was recorded in the female washrooms. However, this result is not conclusive. Firstly, the research was confined to eight taps in one case study building and clearly is not representative of all buildings. Secondly, the standard deviation and maximum water use per event suggests a large variance in how and for what purpose building occupants used the taps. Accordingly, the key research outcome was not necessarily that the flow regulators do not work, but instead that the performance of the flow regulators is highly dependent on the behaviour of the user.

This dependence between the building occupant and efficiency performance is highlighted by Figs. 1 and 2. The research found that when the tap is open less than a quarter-turn the flow rate is largely unaffected by the presence or absence of a flow regulators. However, when the taps are unscrewed by 120 degrees or more, the flow rate becomes regulated to the specified flow regulator rate. A closer looker look at the data also shows that the operational flow rate, when the tap is open one turn or more, is less than the specification (6.0 lpm or 4.0 lpm) flow rate of the flow regulator. These findings indicate the effectiveness of the flow regulator to be dependent on flow rate and water pressure. Unscrewing the tap increases both flow rate and pressure and therefore the effectiveness of the flow regulator is influenced, to an extent, by the building occupant.

The second predominant finding from the data was that the hot tap is used more frequently than the cold tap, in both male and female cubicles. Unfortunately, it is not known why this occurred. The most probable answer stems from the habits of building occupants and perhaps a preference for hot versus cold water. The temperature of the hot tap was regularly checked and found to be acceptable, also hot water is supplied on a flow and return system which supplied hot water instantly. Accordingly, the research findings indicate that it is preferential to focus on improving the water efficiency from hot taps, as they appear to be used more frequently. Additionally reducing hot water consumption use also reduces the energy required for hot water heating.

The research aimed to show the importance of evaluating the operational performance of a water efficiency product. The results from the case study building have clearly demonstrated that the operational performance of the flow regulator was lower than expected with regard to reducing water demand. These findings help underpin the importance of in-use performance evaluation. Additionally, the research results are beneficial to support further research proposals targeted at testing water efficiency products during every day operation.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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