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Gone down the drain:
water wastage from public toilets

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EXECUTIVE SUMMARY

Despite our unique situation as an island with limited water resources, Singapore has surpassed many milestones in the area of water quality and access. Technological advances alongside an efficient water infrastructure and regulatory policies have fortified our water supply.

In keeping water consumption efficient in public toilets, the National Environment Agency (NEA) has regulations for the maximum use of water in flushing cisterns. This is coupled with **automated** flushing cisterns to remove waste and maintain hygiene.

However, automated flushing cisterns have inadvertently added to the problem of water wastage through excess flushing due to the sensor sensitivity. This study assesses the frequency with which automated systems flush more times than necessary per use. We quantified the amount of water wasted, financial costs and the energy used to produce the water. Women users were focused on as women use pedestal toilets exclusively, and therefore the problem is more pronounced in women's toilets.

Findings

- More than 60% of women experience between one and two extra flushes per use.
- Close to 40% experience extra flushing at least once a day.
- The infra-red sensor systems are unable to accurately detect the behaviour of over 90% of women surveyed.

Water Wastage

Two scenarios were generated to assess the quantity of water wasted over the course of one year. Scenario 1, based on the lower end of extra flushes, led to 15,840 litres of water wasted in one year while Scenario 2, based on the higher end, led to 43,200 litres of water wasted.

The current method of identifying water loss uses spikes in water consumption to identify excess water usage in toilets. However, an overactive cistern is not necessarily identified as faulty, and this may mask the entire problem.

Overall, three factors contribute to this problem – sensor technology does not match behaviour, absence of feedback from users, and imprecise identification of baseline water consumption.

1.0 INTRODUCTION

Singapore's rise as a world leader in water management and infrastructure has been demonstrated through the implementation of a progressive water policy, as well as efficient infrastructure and innovative technology. While we have achieved much in the area of water quality and access, our unique situation as an island with limited water resources poses challenges in water resilience.

Building Water Resilience

Singapore's limited geographic size and dense urbanisation prevent rainwater catchment from providing for all our water needs (Tortajada & Buurman, 2017). As a result, Singapore built up resilience by diversifying water resources – also known as the 4 National Taps. The 4 National Taps are made up of imported water from Malaysia, local catchment, desalination, and NEWater. Imported water and rainwater catchment have in the past been two of the largest sources of water accounting for 45%, however both currently make up 30% of Singapore's total water supply (PUB, 2018). The importance of water security isn't limited to potable drinking water. Singapore has a strong industrial sector focused on manufacturing, and oil & gas. These sectors have a high demand for water, which is expected to rise to around 70% of the total water demand by 2060 (PUB, 2018).

Water Security

In 2015, Singapore was named one of the most water stressed countries in the world by the Water Resources Institute (PUB, 2018). Population growth and industrial development has increased our demand for water. The 1962 water agreement between Malaysia and Singapore currently allows Singapore to draw 250 million gallons a day from the Johor river (MFA, 2019).

However, imported water from Malaysia is not without its challenges. Relations regarding water have a history of being precarious between Malaysia and Singapore – disagreements between Malaysia and Singapore have surfaced with Malaysia threatening to cut off water supply multiple times, including in 1986 and 2002 (Today, 2017). In addition to this, the agreement between Malaysia and Singapore is set to expire in 2061, potentially leaving Singapore with one less water source (MFA, 2019).

Water Leakage vs Water Wastage

Aside from decreasing our dependence on imported water while simultaneously increasing our internal water supply, Singapore places emphasis on an efficient water infrastructure that reduces water loss from leakage and wastage. Water loss from leakages (broken pipes or defunct taps) is defined as the amount of distributed drinking water that does not reach customers and that water utilities therefore do not receive payment for (Tortajada & Buurman, 2017). In Singapore, water leakage is pegged at about 5% (Tortajada & Buurman, 2017). In contrast, water wastage is defined as the loss of water that is the result of behaviour, operations, and inefficient processes (Danish EPA, 2017).

Public Toilets

As of 2003, NEA regulation requires all public toilets to “incorporate the use of sensor operated flush valves”, which use no more than 4.5L for a single flush (NEA, 2004). This system has been put in place to effectively flush waste and maintain hygiene. User feedback has identified flushing mechanisms in women’s toilets as being overactive - flushing more times than necessary during a single use. These extra flushes are a form of water wastage - but just how big is this problem?

This study assesses the frequency of extra flushes, and amount of water wasted in women’s public toilets.

2.0 PROJECT OBJECTIVE

Automated toilets use infra-red sensors to pick up on user behaviour so the flushing mechanism can be activated when the user is done. Based on user feedback, automated flushing systems have a tendency to go off when they are not supposed to e.g. upon entry into a cubicle or while still in use.

This study assesses the frequency with which automated systems flush more than once per use. We quantify the amount of water wasted and associated financial costs and energy use. We focused on using women's feedback to assess the extent of the problem as women use pedestal toilets exclusively and therefore the problem is more pronounced.

3.0 METHODOLOGY

Survey

This survey focuses on public restrooms within the One North area, specifically Fusionopolis and Blocks 71, 73, 75, 77, and 79. Most of the women surveyed were assessed to be working in this area. Surveys were carried out in person or online via QR codes posted in the toilets of Blocks 71, 73, 75, 77, and 79. The surveying process took place over one month from mid June to mid July 2019. In total, 74 responses were collected.

Parameters

Table 1 displays the values used to calculate the following variables: quantity of water, energy and cost.

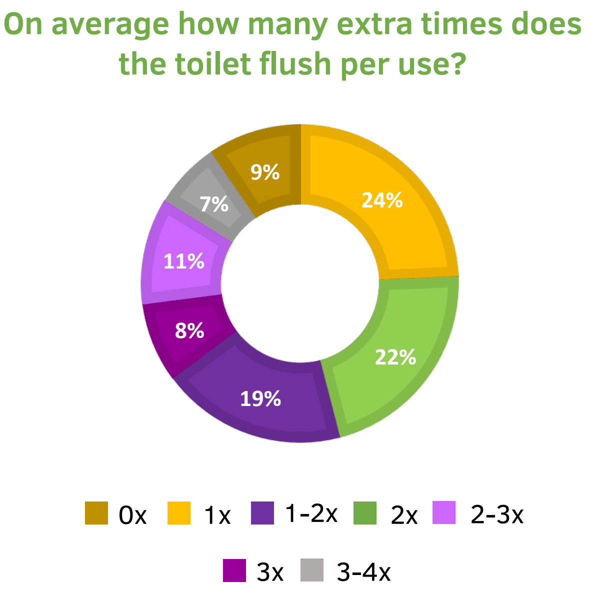
Feedback

Feedback on the problem was gathered from individuals in facilities management, academia, toilet supplier and an NGO.

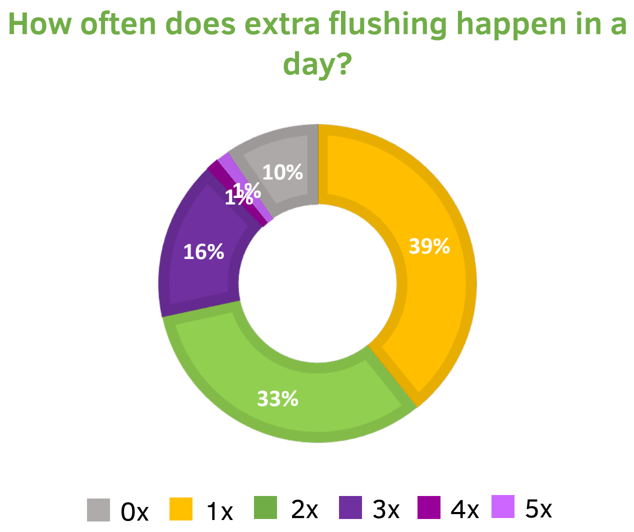
Table 1. Values used to calculate the quantity of water, energy and cost.

Variables	Value	Reference
Energy (Public Utilities Board)		
Desalination	3.5kWh/m^3	Public Utilities Board, 2018
Catchment	1.9kWh/m^3	Public Utilities Board, 2012
Carbon Emissions (Energy Market Authority)		
Desalination	0.4192kg/kWh	Energy Market Authority, 2017
Catchment	0.4192kg/kWh	Energy Market Authority, 2017
Water Usage - Auto Flush		
Rigel AFS101DOMKDF	3.0L per flush	Rigel Technology, 2019
Rigel AFS101CAISDFe	3.0L per flush	Rigel Technology, 2019
AWS 710ACL	No more than 4.5L per flush	Venus Technology, 2014
TOTO DCE608UVG	4.5L per flush	TOTO
Water Cost (Public Utilities Board)		
Business Pricing	\$2.74/m^3	Public Utilities Board, 2018

4.0 FINDINGS



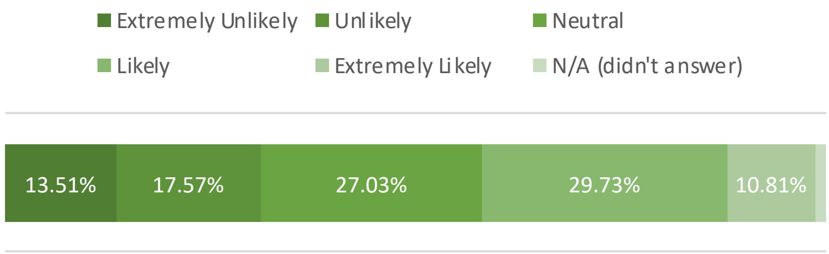
Over 60% (N=74) of women surveyed experience between 1 and 2 extra flushes per use. Less than 10% of women did not experience extra flushes. This means the sensors cannot accurately read the behaviour of over 90% of users surveyed.

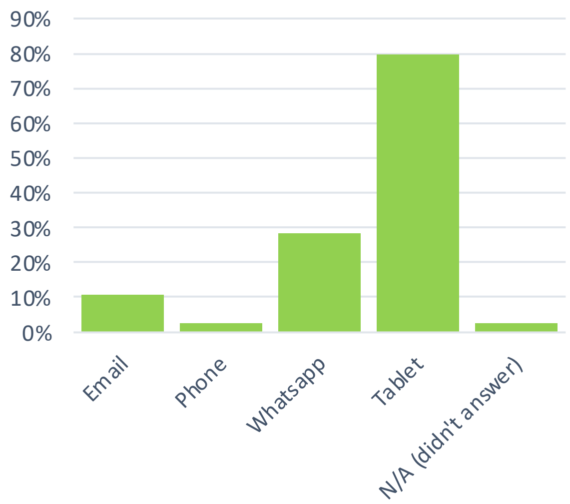


Close to 70% (N=74) of women surveyed experience extra flushing once or twice per day.

Feedback

When asked how likely they were to give feedback on water wastage in public toilets (bottom left), less than 50% of women were likely to give feedback. In terms of preferred feedback options (bottom right), 11% of women preferred email, 2.7% preferred phone, 28.4% preferred Whatsapp, and 79.7% preferred tablet.





Based on the survey results we generated 2 Scenarios to quantify the extent of water wasted.

Scenario 1: 22 out of every 100 women experience 1 extra flush one time a day.

Over the course of one year, 22 users will lead to a total waste of 15,840L of water. The amount of energy required to produce this 15,840L via Desalination amounts to 55.4 kWh, which is equal to 23.24kg of CO^2 emissions. Alternatively, the amount of energy required to treat 15,840L of catchment water is 30.1 kWh, equal to 12.62kg CO^2 emissions.

Scenario 2: 15 out of every 100 women experience 2 extra flushes twice a day.

Over the course of one year, 15 users will lead to a total waste of 43,200L of water. The amount of energy required to produce this 43,200L via desalination amounts to 151.2 kWh, which is equal to 63.38kg of CO^2 emissions. Alternatively, the amount of energy required to treat 43,200L of catchment water is the 82.1 kWh, equal to 34.41kg CO^2 emissions.

Table 2. Scenario 1 & 2 showing the associated costs of water wastage.

	Total Water Wasted*	Energy	Carbon Footprint Kg CO^2 eq.	Water Source
Scenario 1	15,840L	55.4 kWh	23.24 kg	Desalination
		30.1 kWh	12.62 kg	Catchment
Scenario 2	43,200L	151.2 kWh	63.38 kg	Desalination
		82.1 kWh	34.41 kg	Catchment

*Automated flushes are set to 3L in general (see Table 1). Water wasted in one day was multiplied by 5 days for one work week, and from that a yearly value was derived.

The amount of water wasted in Scenario 1 is enough for one person to drink 8 glasses of water a day for 22 years, or in Scenario 2 for 60 years.

5.0 UNCOVERING PITFALLS

In an effort to improve water efficiency, PUB has upgraded hydraulic system toilets to automated low-capacity cisterns. Since 2003, NEA regulation requires all public toilets to use no more than 4.5L per flush (NEA, 2004). This is complemented by water efficient low capacity cisterns (3.5L per flush) (PUB, 2019). Water efficiency via optimally functioning equipment is essential to reducing water wastage. However, as identified in this study, water wastage can occur through other means.

1. Ensure equipment are functioning optimally

One of the primary focus areas of public toilets is ensuring waste is flushed effectively. So long as the flushing cistern succeeds in disposing of all waste with minimal use of water, cisterns are seen to be working. In our conversation with various stakeholders excess flushing, as an issue, was overlooked – possibly because it does not hamper waste disposal, nor can it be labelled definitively as defective equipment.

In addressing water efficiency, stakeholders must check that their equipment is both effective (in removing waste) and efficient (least amount of water using a *single flush only*).

2. Current technology & human behaviour

The sensors of public toilets operate based on an infrared sensor system. This system is designed to detect a user's movement over the course of several second-long intervals in order to effectively time a flush. This system works on the premise that user behaviour is defined and predictable, and sensors can be programmed accordingly. As seen by our survey, this is in fact false - the sensor programme was not able to detect the behaviour of over 90% of women surveyed. Different users exhibit different behaviours on the toilet which increases movement e.g. adjusting clothing or hair, or using mobile phones.

This movement is erroneously picked up as an indication that the user is finished with the toilet. The current sensor technology is not sophisticated enough to capture a range of human behaviour, rather it is only able to detect the presence or absence of a person. Jerome Barth, director of operations for a New York park who's public toilets serve around 700 thousand users per year remarked, "automated toilets are designed as functional machines, not to create an environment for real people to use" (Braverman, 2010). Alternative approaches should be considered, such as placing the sensor at a different point in the toilet or using the opening and closing of cubicle doors to trigger flushing, which would be more accurate.

3. Gender considerations

Feedback from various stakeholders we interviewed echoed the observation that technicians and contractors tasked with renovating, building or maintaining toilet equipment are largely men. Arguably, a male-dominated industry provides less opportunity for recognising the extent of water wastage from overactive cisterns.

This is compounded by the fact that the majority of women surveyed were not likely to provide feedback on the issue.

This disconnect between women users and facilities management likely stems from the general inclination to not discuss "toilet matters", not recognising water wastage, and acceptance of design flaws.

(i) Feedback on "toilet matters"

The problem of extra flushing is not widely talked about – just how many women would report that extra flushing hampers user experience? This is exacerbated by limited options for actual feedback – most feedback channels focus on cleanliness and overall user experience, not water wastage.

In order to get a wider grip of the problem of water wastage caused by excess flushing, targeted feedback options need to be widely available and accessible in public toilets. Eighty percent of women surveyed in this study said they would prefer to use a tablet (Figure 1) for providing feedback on water wastage. These tablets are widely in use, and could be fitted with an option for water wastage in addition to cleanliness and overall experience. Additionally, tablets could be put in individual cubicles for more immediate, accurate feedback on water wastage.

Figure 1. Example of tablet provided in public toilets for feedback.

(ii) Design

Women are also more accustomed to living with products that are not suitable, specifically in terms of design specifications. In the automobile industry, female crash test dummies are not widely used, and when they are, they are often not the correct measurements for the average woman. This has made cars more dangerous for women, with women being "47% more likely to be seriously injured, and 71% more likely to be moderately injured" in a car crash, "even when researchers control for factors such as height, weight, seatbelt usage, and crash intensity" (Criado-Perez, 2019). Having to deal with hardware that does not fit has made women more accepting of design flaws in their everyday lives. This has led to a common behaviour of passivity when faced with things that need re-designing, rather than repairing.

In the process of constructing public toilets, feedback from women should be actively sought and incorporated as a means of maintaining effective & efficient equipment. Having more women in facilities management and/or design teams may help mediate the imbalance.

(iii) Baseline Water Usage

Women's toilets have an assumed higher consumption of water compared to male toilets. In trying to establish the baseline water usage for women's toilets, we were told by facilities management there is not one. Excess water use is identified by reading spikes from the water meter over time – this approach may be masking water wastage. For instance, if water usage starts off high through excess flushing, there is no way to identify it as a problem. Baseline water consumption should be measured according to how frequent toilets are used – which would be more accurate indicator.

6.0 CONCLUSION

Essentially, there are three factors that contribute to this problem – sensor technology does not match behaviour, absence of feedback and imprecise identification of baseline water consumption. The problem is not being highlighted to maintenance personnel as users are not giving feedback. Facilities management is failing to see the problem because their focus is on maintaining cleanliness and fixing leaks – excess flushing falls into a grey space. That the problem occurs in individual cubicles prevents maintenance personnel from recognising that automated cisterns are not working as they should be. In order to resolve this problem active feedback, better technology or re-designing sensor placement needs to be considered.

Surveying a larger number of women across different areas would provide a more complete understanding of the extent of water wastage, and if any particular installations/equipment are more prone to excess flushing. After all, we should not be flushing a precious resource down the drain.

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APPENDIX - HOW AUTOMATED SENSORS WORK

User enters cubicle and the sensor detects user in the cubicle. Users are only detected as using the toilet if the sensor picks them up for the allotted detection time (ranges from 5-7 seconds based on the cistern models we've observed). After this detection period, the sensor goes into standby mode, where it is waiting to detect user has left, then it waits for a period of 6-7 seconds before it initiates a flush. This standby mode can be seen with the blinking sensor eye, and the initiating flush period can be seen as the blinking eye with changing colours depending on the model of the sensor.

For some models, distance is a factor where the sensor is able to detect movement up to a certain distance.

Breakdown of process:

- Sensor detects person in cubicle
- Sensor waits 5-7 seconds to make sure someone is not passing through e.g. cleaner
- Sensor goes into standby mode to wait for user to leave toilet (sensors have a distance to detect presence and absence)
- After user leaves and sensor detects it and after 6-7 seconds, toilet flushes

Based on our observations, the sensor detects "forward movement" as the user leaving even though they are still seated. Also based on our observations, we noticed that the detection and/or standby mode is too short for users that may use the toilet longer, therefore the flushes go off quicker. This is also largely influenced by behaviour in the toilet.

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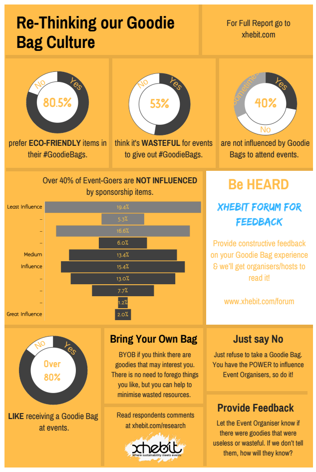

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