What is a Water Efficient Canteen?

Team Nyx (RVTeam2)

River Valley High School

Singapore

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Abstract

Singapore has the world's third highest population density, with 5.6 million people inhabiting 719.1km^2 of land. This poses a perpetual challenge to Singapore's water sustainability given her limited land area and natural water catchment. This research addresses the issue of water sustainability by exploring the concept of self-sufficiency at the micro-scale of water usage in a school canteen. An investigation into the infrastructural design of our school canteen and water usage culture of students was conducted using spatial analysis of the canteen's sink and outlet layout, in-depth surveys of canteen stakeholders and observational data of water usage habits. Insights derived from the principles of water efficiency, such as water recycling and waste minimization were then used to design a water efficient canteen as a viable modification and improvement of current infrastructure as well as social norms such as the consciousness of water wastage. Incorporating both engineering strategies to improve water usage efficiency as well as initiatives to effect social change in school, the research outcome is a blueprint that incorporates proposed solutions to achieve a water efficient canteen.

Keywords: Water Sustainability, Canteen Design, Social Responsibility, Schools, Singapore

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1 Introduction

1.1 Singapore's Water Resources

Singapore faces issues of water insecurity due to limited land space and resource scarcity. Singapore is one of the most water stressed countries in the world according to a World Resource Institute study, with a baseline water stress score of 5.00 (Maddocks, 2015). Imported water, one of Singapore's Four National Taps, helps meet the daily 430 million gallons (mgd) water demand (PUB Singapore Water Story, 2017). Water shortage is an imminent threat, as we cannot guarantee the security of our water supply. Therefore, water conservation will reduce our dependence on imported water, and contribute to our goal of a more self-sufficient nation. In line with Singapore's national agenda, this research project focuses on water efficiency in school canteens.

1.2 Water Efficient Amenities in Schools

The Singapore Public Utilities Board (PUB) launched the Water Efficiency Labelling Scheme (WELS) in 2006, targeting water fittings and appliances, to encourage nationwide water sustainability. Notable education institutions like Riverside Secondary School have achieved the Water Efficient Building Certification and obtained the PUB's Watermark Award.

2 Purpose of Research

2.1 Rationale

The school canteen (Figure 1) has the greatest potential for water recycling and conservation as it constitutes the greatest proportion of water consumption in River Valley High School. We believe that with additional infrastructural modifications and a change in social consciousness of our stakeholders, we can effectuate plausible changes to the water usage patterns in the school. And with that, we hope to inculcate water efficient practices amongst the school body to ensure the sustainability of the research project.

Figure 1: Picture of the School Canteen

2.3 Research Aim

Our research project aims to design a water efficient canteen to achieve the aim of reducing our school canteen's total water usage and wastage by at least 10% from the existing amount and to ensure long term sustainability.

2.4 Research Questions

To achieve this, we sought to answer three research questions:

1. What water conservation systems can be implemented on top of existing ones to maximise water usage?
2. What proportion of used water in our canteen can be recycled using water recycling systems to achieve a water efficient canteen?
3. How can we ensure the sustainability of our proposed water efficient canteen?

3 Research Method

For the first research question we had to find out about the school's existing water usage at various water points. For example, at the canteen's wash basins (Figure 2) we measured the rate of flow of each tap using Eq.(1). Secondary research was conducted to find different types of tap models and their respective flow rates, to compare the differences in water efficiency.

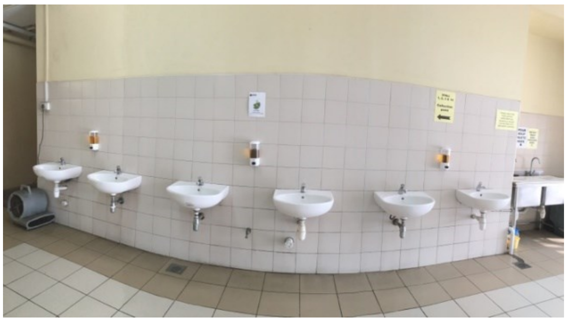
Figure 2: Picture of the public wash basins

$$\text{Rate of Flow (m}\ell\text{/s)} = \frac{\textit{Volume of water dispensed } (m\ell)}{\textit{Time taken to dispense the volume } (s)}$$

Equation (1)


Figure 3: Picture showing the process of measuring the rate of flow

In order to answer our second research question, we conducted a water audit to find out about the main uses of water, and the total volume of water used in the school canteen (mainly from food preparation and washing). The water audit and data was gathered through

- Onsite observation of water usage at all the wash basins (public areas and in the food stalls)for one month
- Water utilities bills from canteen vendors
- Interviews with 5 canteen vendors to find out their daily water usage and habits (*Refer to Annex A: Interview Responses for Canteen Stall Vendors for details*)

From our observation of water use in the canteen, we then identified the types and estimated the amount of waste water that can be reused, also known as 'greywater', water that can be recycled for non-potable use in the school (Sustainable Earth Technologies, n.d.).

Subsequently, we conducted water quality testing on the greywater samples produced in the canteen to qualify which greywater source has potential for recycling.

Figure 4: Pictures of our team conducting water quality tests

For the third research question, we conducted a survey *(Refer to Annex D: Student Survey*) on to find out current attitudes and receptiveness of the students towards trying out new strategies to conserve water.

4 Research Findings

4.1 Research Question 1

From our primary data collection, we found out that the average rate of flow is 2.4 L/minute.

We have also found:

1. the rate of water flow for all six taps differed from each other due to wear and tear, and
2. varied water usage patterns by consumers

From secondary data sources we identified the standards for the other taps available in the market, to compare the water efficiency of our school canteen taps.

	Basin Tap	Cold Water Bib Tap	(Motion) Sensor Tap
Tap Models			
Water Flow Rate	4.5L/minute	4.5L/minute	2.0L/minute
Water Savings	25%	-	66%
WELS Rating	✓✓ (Very Good)	✓✓ (Very Good)	✓✓✓ (Excellent)
Others	-	-	- Water Consumption: 10 secs - Faucet: 0.35 litre per cycle - Saving Feature : Auto cut-off when hands are removed

Figure 5: Table of various tap models from secondary research (*Refer to Annex B: Types of taps for the enlarged version)*

4.1.1 Analysis of results

When compared to the Water Efficient Flow Rates of 2L / min by PUB, the current rate of flow of our canteen wash basin exceeds the standard by 0.4L / min. This means that our current wash basin taps' rate of flow is not water efficient. The inconsistent rate of water flow across the six taps and the varied water usage patterns by consumers incurred excessive water usage.

Comparing the type of taps available in the market, we found out that the motion sensor tap is the most water efficient (i.e. slowest rate of water flow), and received the highest percentage of water saving capability listed by the PUB. Also, the motion sensor tap has an 'Excellent' Water Efficiency Labelling Scheme rating (WELS). This labelling scheme is a grading system by PUB of 0/1/2/3 ticks to reflect the water efficiency level of a product. 3 ticks equate to an excellent rating, which is the highest water efficiency label a product can attain (Public Utilities Board, 2014).

Furthermore, the rate of flow is not restricted to a fixed duration, and users can use the taps on their own accord, which increases the likelihood of the users opting to cut down their water usage. Therefore, it maximises water usage and reduces water wastage at the wash basins.

As such, since the rate of water flow of our current average tap does not meet the PUB's criteria for water efficiency, we propose to change the canteen wash basin taps to motion sensor taps to reduce water usage.

4.2 Research Question 2

4.2.1 Results from Water Audit and Interviews

From our water audit (Figure 6), 42% of the total volume of water used in the canteen can be recycled per month.

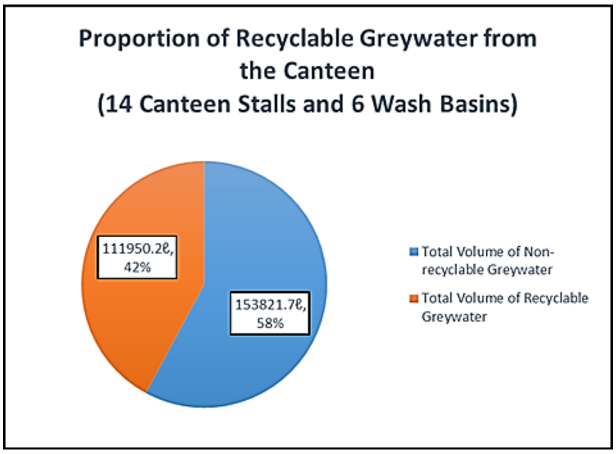

Figure 6: Pie chart showing the proportion of recyclable greywater from the Canteen

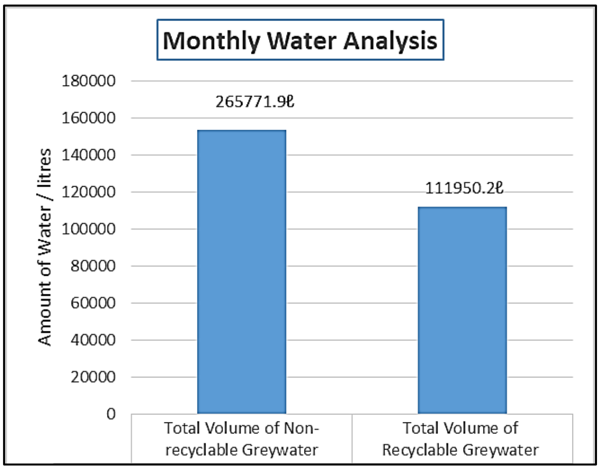

Figure 7: Bar graph showing monthly water analysis

We also determined that the total volume of non-recyclable greywater per month is 265771.9ℓ, and the total volume of recyclable greywater per month is 111950.2 ℓ (Figure 7).

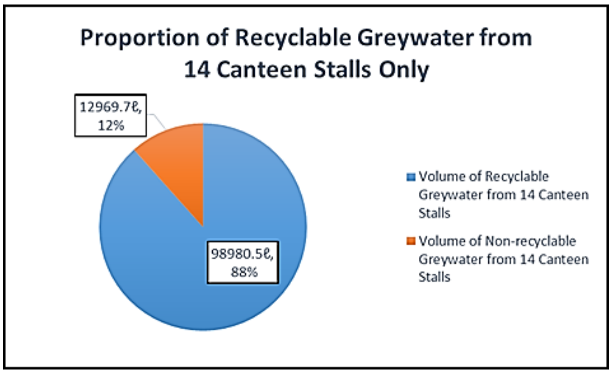

Figure 8: Pie chart showing proportion of recyclable greywater from the canteen stall

According to the results from the water quality tests and physical observations of water usage at the canteen wash basins, we have found that the total volume of water used for the most common activity at the canteen wash basin taps is 563.9 litres of water per day, and the total volume of water used for the second most common activity at the canteen wash basin taps is 69.7 litres of water daily.

From our water audit, 88% of the total volume of water used from 14 canteen stalls can be recycled per month (Figure 8).

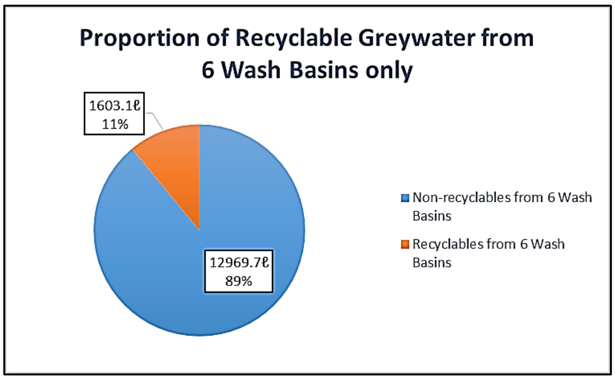

Figure 9: Pie chart showing proportion of recyclable greywater from 6 wash basins only

Water Consumption (Daily) at Public Wash Basins
From our water audit, **89%** of the total volume of water used at the canteen wash basins can be recycled per month (Figure 9).

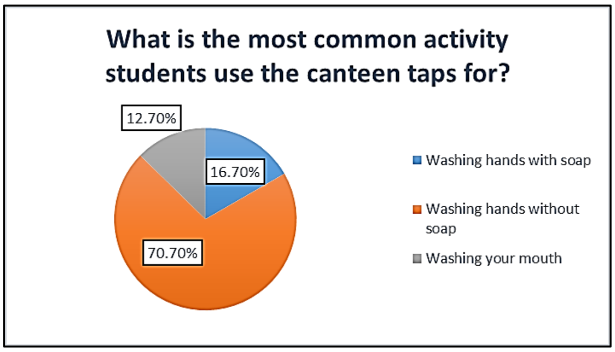

Figure 10: Pie chart showing most common activities students use canteen taps for

From the online survey sent out to students, the responses indicated that the two most common activities at the wash basins are (by ranking) – handwashing without soap, and handwashing with soap and washing their mouths (Figure 10). *(Refer to Annex E: Student Survey for data)*

PUB Guidelines for Treated Greywater Quality *(Refer to Annex H)*

Results of Water Quality Test

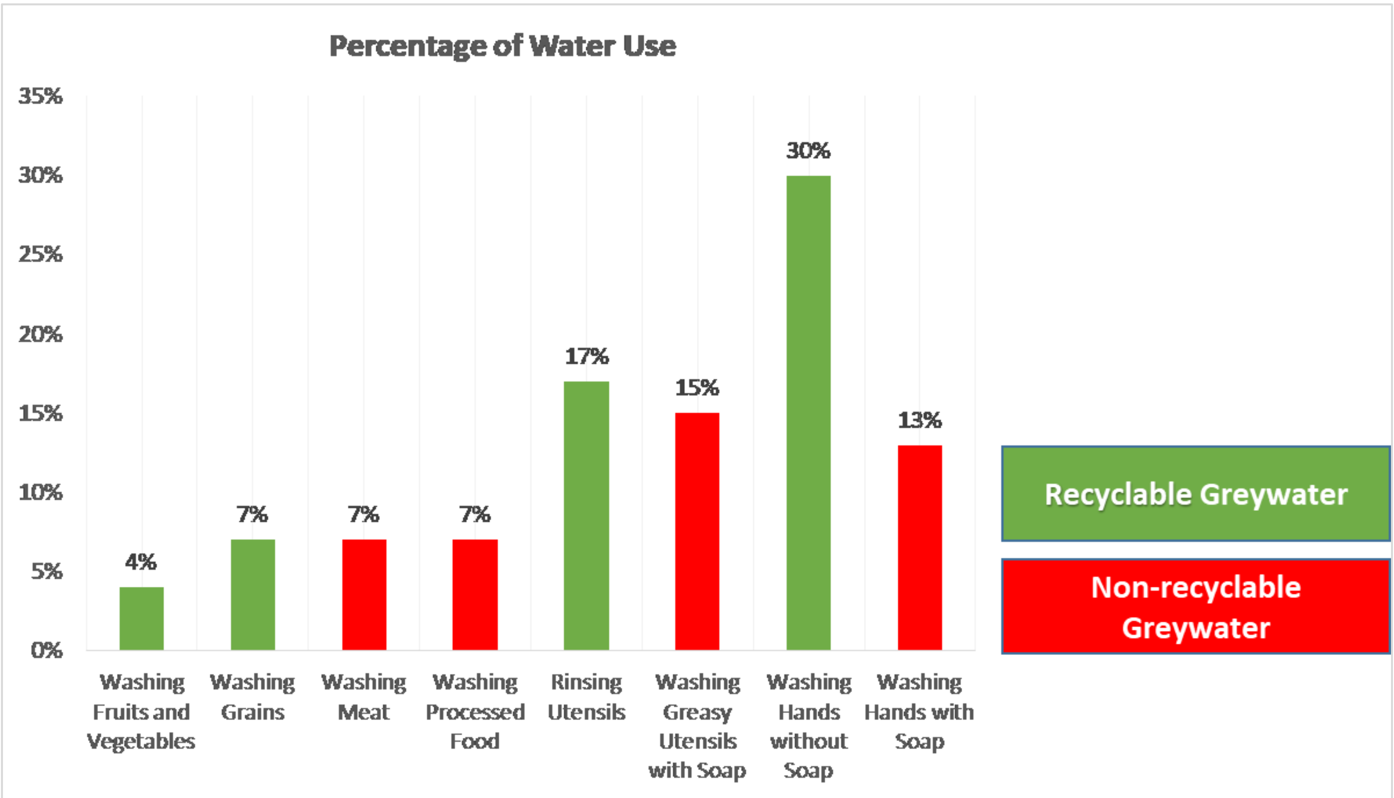

Figure 11: Bar graph showing Percentage Types of water use in the canteen

After water quality testing, all eight categories did not satisfy the PUB Greywater Requirements, however disinfection treatment will deem 4 categories suitable for recycling.

The four categories were identified because they met all but 2 of the water parameter guidelines, those of E.coli count and turbidity, while the rest failed in more parameters (see Annex J for details of findings.) The percentage of recyclable greywater was then applied to the total water usage shown in Figure 12 to estimate the potential volume of greywater that can be recycled in the canteen as shown in Figure 13.

	Amount / month (23 days)
Total usage of water in the Canteen	265771.9 litres
Total usage of water from the 6 Wash basins	14572.8 litres
Total usage of water from the 14 Canteen Stalls	251199.1 litres

Figure 12: Table showing total volume of water usage in the school canteen

	Amount / month (23 days)
Total recyclables from the Canteen	111950.2 litres
Recyclables from the 6 Wash basins	12969.7 litres
Recyclables from 1 Canteen Stall	7070.2 litres
Recyclables from 14 Canteen Stalls	98980.5 litres

Figure 13: Table showing the total volume of water that can be recycled

Each water use activity generates greywater, which is used water that does not contain toxic chemicals. Using the PUB parameters for greywater recycling, (Annex H), we determined the categories containing recyclable greywater for non-potable use.

After conducting water quality tests for each greywater sample, we have compared them with PUB's greywater requirements. The greywater samples that fulfilled all seven greywater requirements will be deemed as fit for recycling.

Although we identified four categories of recyclable greywater in our canteen based on the PUB guidelines, our water quality tests actually indicate that some categories did not pass the respective tests:

Turbidity
The greywater samples for "Washing Grains" have a white colouration due to starch in the grains, which makes samples 'cloudy'. The sample fulfils all greywater requirements, except for the turbidity and *E. coli* tests. However, the greywater is still deemed recyclable.

E. coli
Samples should have non-detectable traces of *E. coli* to be deemed suitable for recycling. This requirement rendered six out of eight greywater samples to be unfit for recycling. However, secondary research showed that addition of chlorine would inhibit the growth of *E. coli.* Therefore, to recycle 37% more water in the canteen, we could use chlorine to allow two more sources to be deemed recyclable.

As such, although some of the greywater samples fulfilled all but one of the greywater requirements, the greywater sample can still be considered for recycling, only, with the addition of a disinfectant. This will be addressed in our Proposed Solution.

4.3 Research Question 3

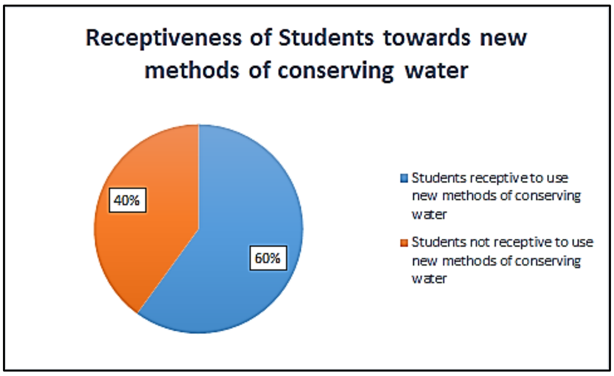

Figure 14: Pie chart showing the receptiveness of students towards new methods of conserving water

According to our survey results, 60.3% of the respondents (105 out of 174) were willing to use the designated sinks.

Our survey results show that students are receptive towards change in the school canteen. This will mean that we can expect support from the majority regardless of the nature of our proposed solution as they want to save water.

5 Proposed Solutions

The aim of this project is to design a water efficient school canteen. The blueprint is a consolidation of all our proposed solutions.

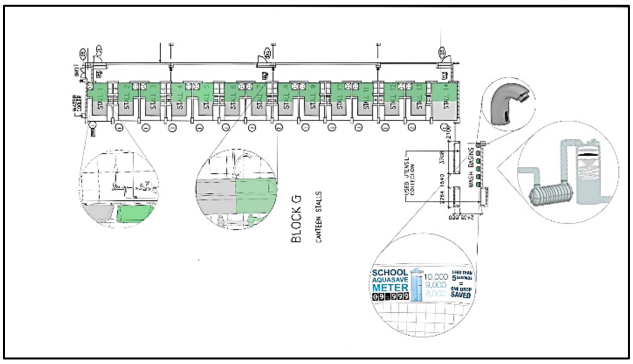

Figure 15: Overarching Blueprint of 4 Solutions in Water Efficient Canteen
(Refer to Annex K for enlarged version)

5.1 First Solution: Change the Model of Taps at the Canteen Wash Basins

We propose to change the existing canteen wash basin taps to motion sensor taps, namely the W3-R-ST102SSN Deck Mounted Sensor Tap model (Figure 16). This model is recommended by the PUB under the WELS, being ranked as 'excellent'. Changing the tap model to a more water efficient one would help to reduce the school's water consumption, saving 2210.2 litres per month.

Figure 16: Deck Mounted Sensor Tap model

5.2 Second Solution: Designate Sinks for Allocated Uses

Designate Canteen Vendors' Sinks

Figure 17: Picture of the current sink inside the canteen stalls

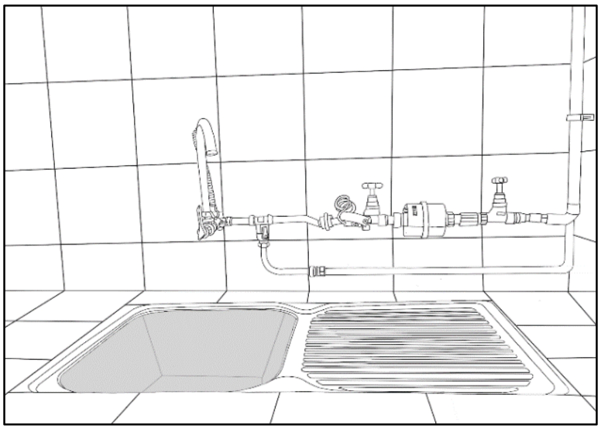

Figure 18: Sinks inside canteen stalls (before)

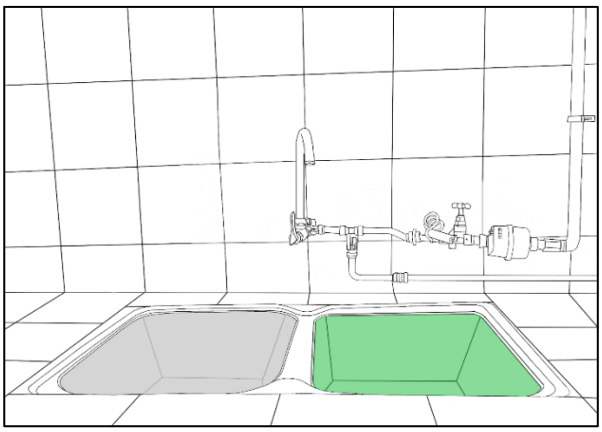

Figure 19: Proposed change to sinks inside canteen stalls (after)

We propose for the canteen stall vendors' basins to be changed from the trough kitchen sink type (Figure 18) to a double bowl kitchen sink (Figure 19). The double bowl kitchen sink is partitioned such that the right sink would be specifically for water usage that produces recyclable greywater, and the left will be for non-recyclable greywater.

Figure 20: Picture of the current sinks for two canteen stallholders to use

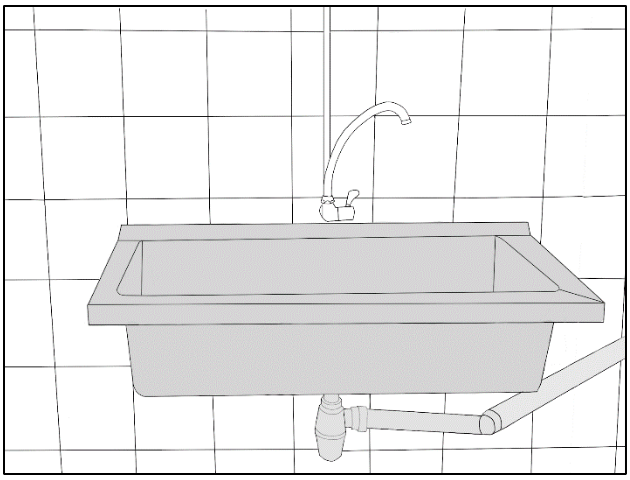

Figure 21: Before proposed changes: sinks outside canteen stalls

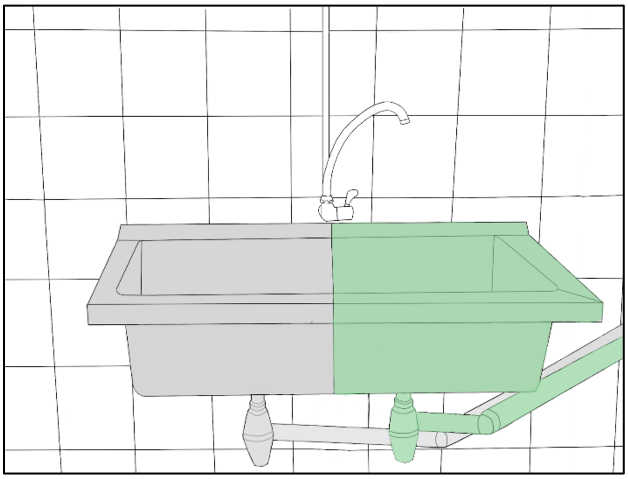

Figure 22: After proposed changes: sinks outside canteen stalls

Pipe routing from the designated sinks in each canteen stall will be installed to transfer greywater of potential recyclability into a central storage tank, while non-recyclable greywater will directly enter the drainage pipes.

Designate Canteen Wash Basin Sinks

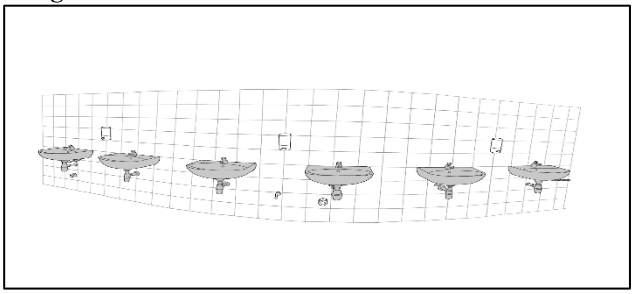

Figure 23: Before: Current canteen wash basins

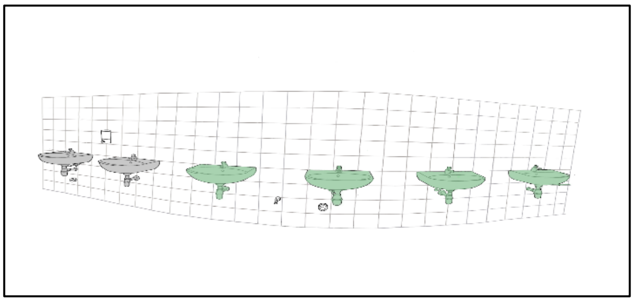

Figure 24: After: colour-coding of the canteen wash basins to indicate water use

For the six public wash basins, they will be designated for recyclable water usage and non-recyclable water usage, namely, for light washing (without soap) indicated by the green sinks, and heavy-duty washing (with soap) indicated by the grey sinks respectively.

We propose to designate two wash basins for light washing and the remaining two wash basins for heavy-duty washing. By designating sinks for each type of water use, it is easier to channel and collect the recyclable greywater to the central storage tank which will be subsequently treated in a water purification system before reuse (e.g., flushing of school toilets).

We suggest to colour-code the wash basins and sinks such that it is easy for users to identify which is for light or heavy washing. Figures 22 and 24 show our proposed modifications, the sinks and basins coloured green and grey are for recyclable and non-recyclable greywater respectively.

5.3 Third Solution: Water Purification System (WPS)

This solution is a development of our second solution. Greywater that is suitable for recycling will be channelled from the respective designated sinks to the Water Purification System (WPS), located in the vicinity behind the school canteen (Figure 25). This is the optimum location to place the WPS as it is located in close proximity to the canteen and the canteen toilets.

Figure 25: Proposed location and scale of the WPS (human figure provided to show scale)

As the greywater channelled to the WPS already satisfies the criteria of the national standard for recycled water, the disinfection stages in the WPS are more of a precautionary measure to inhibit microorganism growth and reproduction, and to maintain the quality of the recyclable greywater.

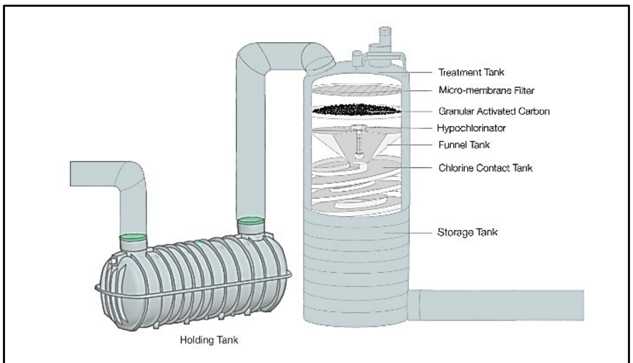

Fig. 26: Artist's impression of the WPS.
(Refer to Annex L for enlarged version)

In the first step, the recyclable greywater from the designated sinks will be channelled to the WPS. It will be pumped up by a Low Lift Pump Well into the top of the WPS, where the water will enter the system and flow through the purification stages utilising the effects of gravity. The Well will have a capacity of 5000L to accommodate the average daily greywater produced in the canteen.

At the initial stage before purification, the greywater will have to permeate through a micro-membrane filter, in a process called 'sedimentation', which will sieve out any microorganisms or sediments that may be retained in the greywater.

The greywater will then enter the Pre-Oxidation Primary Disinfection stage, which is layered with Granular Activated Carbon (GAC). GAC is capable of extracting volatile organic compounds from the aqueous medium, but this particular characteristic is not essential for the purification process of the greywater generated from the school canteen. As the greywater produced from the canteen already fulfils the national requirements for greywater recycling, the purification system will only tap on the other features of the GAC. It is also useful for eliminating odour and acrid tastes of the greywater, but since the greywater will be purified and recycled for non-potable use, its function for eliminating odour is most applicable to the system. An additional feature of the GAC is that it can also be used for sedimentation, in which microbes and pathogens that bypassed the membrane filter will be extracted from the greywater.

Subsequently, the greywater will be released into the next chamber for the Secondary Disinfection stage, called 'CT Disinfection' (Rush, B., 2002). Aqueous Chlorine will be introduced to the greywater through a Hypochlorinator Device. After the chlorine has been introduced to the distilled greywater, it will be funnelled to a Chlorine Contact Tank (Washington State Department of Health, 2016). This is to allow for sufficient diffusion of the aqueous chlorine into the greywater distillation. The Chlorine Contact Tank in the WPS is an alteration of the conventional design of Chlorine Contact Tanks used in surface water purification. To measure the efficacy of Chlorine Disinfection Treatment, there are two major considerations. This can be represented in the equation depicted below.

CT measures the effectiveness of a disinfection process.

CT = *Concentration of Free Chlorine* ($C_{mg/L}$) × *Contact Time* ($T_{minutes}$)

Free Chlorine = *Concentration measured in milligrams per liter (mg/L)*

Equation (2)

The two factors are:

- The concentration of free chlorine in the suspension and,
- The total contact time between the free chlorine residual and the water to be treated

The product of the two factors will equate to the CT Value, which is used to demonstrate the degree of effective disinfection treatment of the water. The international CT Standard Value is 6mg a minute per litre. The average daily volume of recyclable greywater produced in the school canteen is 4870 litres. Given that the volume of water we are working with is of a very large magnitude, we plan to optimise the dosage of chlorine by using the highest possible concentration within the limits of the national greywater recycling criteria. According to the PUB Guidelines for Treated Greywater Quality, *(refer to Annex H)* the maximum concentration of total residual chlorine in a solution is 2 mg/L. To find the total contact time that correlates to this concentration, we must take the CT Standard Value divided by the concentration of Total Residual Chlorine. After calculations, the total contact time is 3 minutes. This means that in 3 minutes, 1 litre of greywater can be recycled. We have found that to account for the average daily volume of greywater produced in the canteen, 10.5L should be treated in each cycle, so that within 24 hours, the total amount of greywater can be treated and ready for use.

Concentration of CL_2 = 6 2 mg/L = 3min

Total Litres Recycled with 2mg of Cl_2 added to 1L of greywater = 60min
3min x 24h = 480L

Given average daily volume is 4870L, and rounding off to the nearest thousand value (5000L),
Volume that can be recycled in 3 minutes = 5000⁄480 = 10.4L ≅ 10.5L

Equation (3)

After the treated greywater is suitable for reuse, it would be rerouted to the canteen toilets for flushing purposes. This involves minimal human contact; hence the safety of users is not compromised. Water used per flush is 6 litres, and considering the frequency that the canteen toilets are used, the capacity of the storage tank is sufficient.

5.4 Fourth Solution: Implement a School Aquasave Meter (SAM)

The attitudes of our stakeholders towards our project determine their receptivity to our proposed solutions, thus ultimately ensuring our project's success and long-term sustainability of the water efficient canteen.

To encourage a positive mindset towards water conservation, we propose to implement a School Aquasave Meter (SAM), which is a virtual display to create interest and awareness of positive water-saving habits among school students.

This idea was inspired by an online campaign on the PUB website that uses a virtual meter (Figure 27) to attract user participation- for every water saving tip posted on PUB's social media platforms, a virtual 'drop' is added to the meter, once there is sufficient participation from the public in posting these water saving tips, a reward is generated for the public. For example, at 500,000 drops, PUB sponsored a kayaking trip at MacRitchie Reservoir for less privileged children.

Figure 27: PUB community meter
(Refer to Annex M for enlarged diagram)

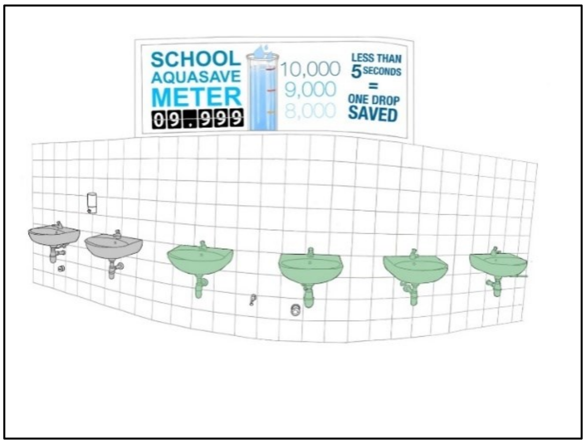

Figure 28: Visual representation of SAM
(Refer to Annex N for enlarged diagram)

The SAM will be mounted prominently above the wash basins at the canteen (Figure 28), connected to every wash basin tap via Bluetooth. If the user's tap usage is under five seconds, this information will be transmitted to the water meter via Bluetooth and a where a virtual water droplet will be added to the display. If the tap usage is 5 seconds and above, water will still be dispensed but there will be no contribution to the SAM. The target volume of drops to accumulate is 41,000 drops per month.

As shown by our survey results, 57% of canteen users use the tap for 4-7 seconds. Hence, the criterion to determine the duration of tap usage to contribute to the SAM was set to make it challenging, yet still feasible to meet.

Its primary objective is to inculcate water efficient practices in the school body. Users will learn about the importance of water conservation, and can see the effects of their effort through the SAM. With a fresh and interactive approach towards water conservation, the canteen users might be more receptive to our project, and their continued support will contribute to the long-term success of our project.

6 Evaluation of our Proposed Solutions

SWOT Analysis

Strengths
Our solutions encompass all areas of the canteen. The approach of targeting different areas, as well as different water amenities in the school canteen will decentralise the conservation of water, such that saving water does indeed constantly happen in all possible areas. Essentially, this projects aids in the conservation of water taking place throughout the canteen, all the time.

While thoroughly considering the receptiveness of the canteen users towards our proposed strategies, we incorporated innovative elements and novel ideas to capture and sustain their interest. This is to ensure their active involvement in making sure that the Water Efficient Canteen can attain its purpose.

Weaknesses
The School Aquasave Meter relies on the use of short-range Bluetooth technology to send the signals to the display monitor which provides an indication when the tap usage is below 5 seconds. Such devices run on a battery-operated system, which require electricity to repower the device. As a result, additional utility costs are induced, contributing to the costs required for this project.

Opportunities
Our research hinges on and embraces the concept of sustainability. With the success of our research project, there will be much emphasis placed on the importance of sustainability. We hope to further expand the concept of sustainability and extend it to other areas, such that certain aspects of our ideas can be applied across different research fields, i.e. energy (electricity), recycling.

Our blueprint serves as a model of development to schools, companies and industries nationwide. Despite being so, there are differences in the dynamics, demography, economic and social conditions of the schools, companies and industries. As such, the procedure has to be recalibrated to suit the nature of the school water usage patterns. Nonetheless, various aspects of our project can still be adopted, and we believe that our research will be able to aid in the consideration and implementation of water saving measures in schools.

Threats
Reduction in water usage and wastage can be attributed to the modifications of the school canteen amenities and not the water usage patterns of the users. The upgrades to the canteen amenities will make them more water efficient, so water is mostly being saved due to the system itself, not because of the user who lacks the consciousness to save water. As such, water conservation comes as a secondary afterthought, as they simply go through the motions of using water for their needs, and yet have already managed to conserve water due to the increased water efficiency rate of the canteen amenities. Even with the implementation of the most water efficient system, there is little value in doing so, since the users are unable to appreciate the significance of saving water.

The implementation of a Water Efficient Blueprint is one that will incur a substantial monetary sum of initial capital to be pumped into. The school authorities provide us with the financial resources essential to actualising our proposed solutions. This means execution of our blueprint is dependent on whether the school authorities concur with the feasibility of our project. If they are not agreeable and are concerned about cost constraints, other alternatives have to be sought to inculcate water conservation habits and the awareness to save water in the school population. This also means that we are unable to achieve the level of water efficiency that we could have by actualising our research project, which is a pity.

7 Key Lessons

Soft Engineering and Hard Engineering
Having analysed the current situation of water conservation in our school, our approach combines feasible infrastructural modification of the canteen water points with strategies to increase awareness for water conservation across the four proposed solutions. This is significant as it targets both the mindset of users, and the technical aspects of the canteen where infrastructure is remodelled to aid in water conservation. The combination of the four solutions helps to minimise the limitation of each individual solution, thus strengthening the sustainability and feasibility of our project. As such, stakeholders understand the importance of water conservation and bring it one step further by taking action instead of waiting for others to take the initiative.

Retrofitting
From our day to day observations and experiences, we felt that the school canteen infrastructure fell short of its optimum operation level. As such, we decided to focus on the existing water systems and upgrade them, with the consideration that small changes in infrastructure and mindsets can effect big changes in improving our school water efficiency. We also considered that inventions have to go through a long interim period before it can be executed as it may require many levels of approval and building code regulations checks before implementation.

Solutions work as an integrated system
The Water Efficient Canteen is one that attempts to close the loop of water usage in the canteen to reduce losses from the system to the bare minimum because water is being repurposed. Furthermore, although there are several solutions, they are not individualised but complement one another as part of an integrated system.

Blueprint for other schools to adopt
Even if the specific retrofitted installations do not apply to all school canteens, the idea of an integrated approach can still be relevant as a reference for other schools to modify their canteen infrastructure.

8 Conclusion

Our project aims to implement water conservation measures to create a water efficient canteen. It is user-friendly, making recycling and reducing water in the canteen less daunting. With the chlorine purification system in place, less effort is required for a higher volume of water to be recycled. By colour-coding the sinks in the canteen, the visual reminder makes it easier for canteen users to identify the sinks catered for specific activities. Not only that, there is also focus placed on changing the mindset of individuals that would make water conservation with this project feasible long-term.

However, we do acknowledge that there are limitations in our project as well, some which are out of the scope of this project. More factors need to be taken into consideration, such as the costs of implementing these measures, then maintaining with regular checks and repairs. Further studies can be conducted to strengthen the feasibility of our project, however, based on the findings and research presented the measures we have suggested are achievable.

With 366 schools island wide, a substantial volume of water would be saved if implemented across schools, industries, and public facilities. It will also promote the development of water conservation habits more effectively, which is of importance in Singapore.

Therefore, through nationwide upscaling, our project has the potential to conserve a significant volume of water. Furthermore, there has been public support for local conservation campaigns, essential for the sustainability and effectiveness of the projects. Hence, we are confident that our project will be likely to receive support, consequently enhancing its feasibility long-term.

To conclude, we believe we have achieved the aim of reducing our school water usage and to create awareness to inculcate positive water saving habits in school.

9 Acknowledgements

This research paper will not be possible without the unwavering support and encouragement from our mentors, family and peers.

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Lastly, we would like to thank our parents and peers who have stood by us throughout this journey and have willingly helped out in one way or another.

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ANNEX A

Interview Responses for Canteen Stall Vendors

Baker's Oven:

1. **How many times a day do you use water for food preparation?**
   Throughout the day.

2. **How many times a day do you wash the used cutlery and trolley?**
   2-3 times daily.

3. **If there are designated sinks in the stall for washing different ingredients such that water like washing vegetables can be recycled, would you be willing to do so?**
   Yes.

4. **Would you be willing to separate your ingredients that you need to wash so that not so dirty water can be recycled?**
   Yes, already doing so.

5. **Do you prefer to have a large sink separated in the middle for vegetables and raw ingredients or do you prefer 2 separate sinks?**
   No preference.

Noodles Recipe:

1. **How many times a day do you use water for food preparation?**
   Throughout the day.

2. **How many times a day do you wash the used cutlery and trolley?**
   2-3 times daily.

3. **If there are designated sinks in the stall for washing different ingredients such that water like washing vegetables can be recycled, would you be willing to do so?**
   Yes.

4. **Would you be willing to separate your ingredients that you need to wash so that not so dirty water can be recycled?**
   Yes, already doing so.

5. **Do you prefer to have a large sink separated in the middle for vegetables and raw ingredients or do you prefer 2 separate sinks?**
   2 separate sinks.

Prata House:

1. **How many times a day do you use water for food preparation?**
   Throughout the day, but will reuse water for washing vegetables for other purposes such as washing the floor.

2. **How many times a day do you wash the used cutlery and trolley?**
   2-3 times daily.

3. **If there are designated sinks in the stall for washing different ingredients such that water like washing vegetables can be recycled, would you be willing to do so?**
   Yes.

4. **Would you be willing to separate your ingredients that you need to wash so that not so dirty water can be recycled?**
   Yes, already doing so.

5. **Do you prefer to have a large sink separated in the middle for vegetables and raw ingredients or do you prefer 2 separate sinks?**
   No preference.

Chinese delights:

1. **How many times a day do you use water for food preparation?**
   Throughout the day.

2. **How many times a day do you wash the used cutlery and trolley?**
   3-4 times daily.

3. **If there are designated sinks in the stall for washing different ingredients such that water like washing vegetables can be recycled, would you be willing to do so?**
   Yes.

4. **Would you be willing to separate your ingredients that you need to wash so that not so dirty water can be recycled?**
   Yes, already doing so.

5. **Do you prefer to have a large sink separated in the middle for vegetables and raw ingredients or do you prefer 2 separate sinks?**
   2 sinks.

Squish:

1. **How many times a day do you use water for food preparation?**
   Throughout the day.

2. **How many times a day do you wash the used cutlery and trolley?**
   6 times daily.

3. **If there are designated sinks in the stall for washing different ingredients such that water like washing vegetables can be recycled, would you be willing to do so?**
   Yes.

4. **Would you be willing to separate your ingredients that you need to wash so that not so dirty water can be recycled?**
   Yes, already doing so.

5. **Do you prefer to have a large sink separated in the middle for vegetables and raw ingredients or do you prefer 2 separate sinks?**
   2 sinks.

ANNEX B

Types of taps

	Basin Tap	Cold Water Bib Tap	(Motion) Sensor Tap
Tap Models			
Water Flow Rate	4.5L/minute	4.5L/minute	2.0L/minute
Water Savings	25%	-	66%
WELS Rating	✓✓ (Very Good)	✓✓ (Very Good)	✓✓✓ (Excellent)
Others	-	-	- Water Consumption: 10 secs - Faucet: 0.35 litre per cycle - Saving Feature : Auto cut-off when hands are removed

ANNEX C

Rate of flow of wash basin taps

Tap (rightwards from toilet)	**Rate of Water Flow, ml / s**				**Rate of Water Flow *l* / min**
	t_1	**t_2**	**t_3**	**<t>**	
1	71.4	71.1	65.8	69.4	4.164
2	47.6	44.1	44.3	45.3	2.718
3	29.6	27.4	25.8	27.6	1.656
4	25.2	26.0	27.8	26.3	1.578
5	49.3	40.7	40.5	43.5	2.610
6	27.3	32.7	32.7	30.6	1.836
Total sum:				242.7	14.6
Total average:				40.6	2.4

ANNEX D

Water Efficiency Requirements for Products

Water Efficiency Requirements for Products

With effect from **1 April 2017**, only 1/2/3-tick WELS rated taps/mixers and 2/3/4-tick WELS rated washing machines shall be allowed for displayed, offered-for-sale, or advertised in Singapore.

Valid from 1 April 2017				
Water Efficiency Rating	**1-Tick** ✓	**2-Tick** ✓✓	**3-Tick** ✓✓✓	**4-Tick** ✓✓✓✓
Mandatory WELS				
Products/Fittings	Flow Rate/Flushing Capacity			
Shower Taps & Mixers	> 7 to 9 litres/min	> 5 to 7 litres/min	5 litres/min or less	NA
Basin Taps & Mixers	> 4 to 6 litres/min	> 2 to 4 litres/min	2 litres/min or less	NA
Sink/Bib Taps & Mixers	> 6 to 8 litres/min	> 4to 6 litres/min	4 litres/min or less	NA
Flushing Cistern (Per Flush)	Dual Flush: > 4 to 4.5 litres (full flush) > 2.5 to 3 litres (reduce flush)	Dual Flush: > 3.5 to 4.0 litres (full flush) > 2.5 to 3 litres (reduce flush)	Dual Flush: 3.5 litres or less (++) (full flush) 2.5 litres or less (reduce flush)	NA
Urinal Flush Valve & Waterless Urinal	> 1 to 1.5 litres	> 0.5 to 1 litres	0.5 litres or less (++) or waterless urinals	NA
Products/Fittings	Wash Volume			
Clothes Washing Machine	NA	> 9 to 12 litres/kg	> 6 to 9 litres/kg	6 litres or less
Voluntary WELS				
Products/Fittings	Flow Rate			
Showerheads	> 7 to 9 litres/min	> 5 to 7 litres/min	5 litres/min or less	NA

Note:

++ PUB to prescribe additional test(s) to be carried out for the Dual-Flush Low Capacity Flushing Cisterns and Urinal Flush Valves with flush volumes below 3.5 litres (full flush) and 0.5 litres respectively.

ANNEX E

Student survey for canteen

174 responses were gathered from the student online survey.

Number of respondents: 174
Age group: 13 years old to 18 years old

Q1. On average, how many times a day do you use the canteen taps?

- 36.8% say twice per day (64 people)
- 35.6% say once per day (62 people)
- 27.6% say others (48 people)

Q2. On average, how long do you use the canteen tap for your most common activity? (washing hands without soap takes around 4 seconds)

- 0-3 sec – 25 people
- 4-7 sec- 99 people
- 8-11 sec- 17 people
- 12-15 sec- 16 people
- 16-19 sec – 15 people
- Above 20 sec – 2 people

Q3. How receptive are you towards trying new methods of conserving water in the canteen?

- Receptive – 105 people
- Not receptive – 69 people

Q4. What is the most common activity you use the canteen taps for?

- Washing hands w/o soap – 74 people
- Wash hand w soap – 49 people
- Quickly rinsing hands- 22 people
- Washing mouth – 29 people

ANNEX F

Categories of the stalls in the canteen

Categories	Noodles	Rice	Baked Goods	Drinks
	Noodles Recipe (S4) That Mian Tan (S5) Yum Mee (S6)	Bagus (S1) Prata House (S2) Chinese Delights (S7) Bon Appetit (S8) V-cuisine (S9) Happy Chicken (S10) Oishii (S11) Yong Tou Fu (S13)	Baker's Oven (S14)	Squish (S12) Sweet Hut (S3)

(The 5 stalls underlined are the ones interviewed. We ensured that there was at least one stall interviewed from each category, such that we could extrapolate the data for other stalls that were not interviewed.)

Total Volume of Water Usage in Canteen Stalls (Monthly)

Stalls	Volume of water use/ Cu M	Volume of water use/ *l*	Recyclable volume of water / *l*	Non-recyclable volume of water / *l*
Bagus (S1)	20.0	20000.0	8000.0	12000.0
Prata House (S2)	20.0	20000.0	8000.0	12000.0
Sweet Hut (S3)	6.9	6900.0	5175.0	1725.0
Noodles Recipe (S4)	18.1	18100.0	7240.0	10860.0
That Mian Tan (S5)	18.1	18100.0	7240.0	10860.0
Yum Mee (S6)	18.1	18100.0	7240.0	10860.0
Chinese Delights (S7)	23.3	23300.0	8155.0	15145.0
Bon Appetit (S8)	23.3	23300.0	8155.0	15145.0
V-cuisine (S9)	23.3	23300.0	8155.0	15145.0
Happy Chicken (S10)	23.3	23300.0	8155.0	15145.0
Oishii (S11)	23.3	23300.0	8155.0	15145.0
Squish (S12)	6.9	6900.0	5175.0	1725.0
Yong Tou Fu (S13)	23.3	23300.0	8155.0	15145.0
Baker's Oven (S14)	3.3	3300.0	1980.0	1320.0
Monthly sum of 14 stalls	251.2	251200.0	98980.0	130629.0

ANNEX G

Volume of Water Usage at Canteen Wash Basins (Monthly)

Duration of use of wash basins is based on timetable from canteen vendor

Days that canteen is open	Duration of use of wash basins/ h	Volume of water used at wash basins / *l*	Recyclable volume of water / *l*	Non-recyclable volume of water / *l*
Monday	4.25	612	544.7	67.3
Tuesday	4.25	612	544.7	67.3
Wednesday	4.25	612	544.7	67.3
Thursday	4.75	684	608.8	75.2
Friday	4.50	648	576.7	71.3
Weekly total:	22	3168	2819.5	348.5
Monthly total:	88	12672	11278	1394

ANNEX H

PUB Guidelines for Treated Greywater Quality

GUIDELINES FOR TREATED GREYWATER QUALITY - FOR RECYCLING OF GREYWATER FOR TOILET FLUSHING, GENERAL WASHING, IRRIGATION AND COOLING TOWER MAKE UP WATER

S.No	PARAMETERS	GUIDELINES FOR TREATED GREYWATER QUALITY – FOR RECYCLING OF GREYWATER FOR TOILET FLUSHING, GENERAL WASHING* & IRRIGATION*	GUIDELINES FOR TREATED GREYWATER QUALITY – FOR RECYCLING OF GREYWATER FOR COOLING TOWER MAKE UP
1	Odour	Non offensive	Non offensive
2	Colour	<15 (in hazen units)	<15 (in hazen units)
3	pH	6-9	6-9
4	Turbidity	<2 NTU	<2 NTU
5	Total Residual Chlorine	0.5 mg/ l to 2 mg/l	0.5 mg/ l to 2 mg/l
6	BOD_5	<5 mg/l	<5 mg/l
7	Total coliform	<10 CFU / 100ml	<10 CFU / 100ml
8	E.*coli*	Non detectable / 100 ml	Non detectable / 100 ml
9	Total *Legionella* count	Not applicable	Non-detectable when tested using the latest ISO 11731, BS6068-4.12, or equivalent method that is able to test total *Legionella* count at or below 1000 CFU/Litre.
10	Standard Plate Count / Heterotrophic Plate count	Not applicable	Maximum 500 CFU/ml

***Note:**
Use of treated greywater for high pressure jet washing, irrigation sprinklers and general washing at markets and food establishments is not allowed to minimise risks and public health concerns.

ANNEX I

Further elaboration of Water Quality Testing

Detailed Rationale for Water Quality Tests

Factor	Reason for investigation in water quality testing
Odour Test	Surface waters may contain dissolved organic or inorganic materials that could affect the appearance of the surface water colour during decomposition. Dissolved organic and inorganic materials may not pose a health hazard to the consumer. The test is used to check the quality of raw or treated water samples, to trace sources of contamination.
pH Test	pH is measured to determine the purity of the solution. This is because many common contaminants, including dissolved air, carbon dioxide and ionic salts, have a direct effect on acidity or basicity of the sample.
Turbidity Test	Turbidity is a key parameter in water supply engineering, because turbidity will both cause water to be aesthetically unpleasant and cause problems in water treatment processes, such as filtration and disinfection. Turbidity is also often used as indicative evidence of the possibility of bacteria being present.
Dissolved Oxygen Test	Surface waters may contain dissolved organic or inorganic materials such as bacteria and microbes. The Dissolved Oxygen test is used to determine the relative concentration of dissolved oxygen in the water sample.
Dissolved Oxygen Test (after 5 days)	After five days, the Dissolved Oxygen Test is repeated with the same water samples that have been incubated for the five days in dark conditions with low humidity. This is because the microorganisms in the water samples have multiplied. The water samples are tested again to ascertain whether the microorganisms have been multiplying at an acceptable rate.
E.coli Test	The bacterium *E. coli* is non-hazardous at small and controlled amounts, however, it can be detrimental to one's state of physical health at extreme levels. The *E. coli* test is used to determine the rate at which the bacterium replicates after 2 days, and can affect potential for recycling.
Hazen Colour Test	Dissolved organic and inorganic materials may not pose as a health hazard to the consumer, but in order to meet the greywater requirements set by the World Health Organisation (WHO), the colour of greywater samples should be of less than 5 hazen colour units (maximum highest desirable units) for aesthetic appeal to the consumers. Otherwise, PUB sets the standard of hazen colour to less than 15 hazen units for recyclable greywater.

ANNEX J

Results of Water Quality Testing

Legend

Recyclable Greywater - Green

Non-Recyclable Greywater - Red

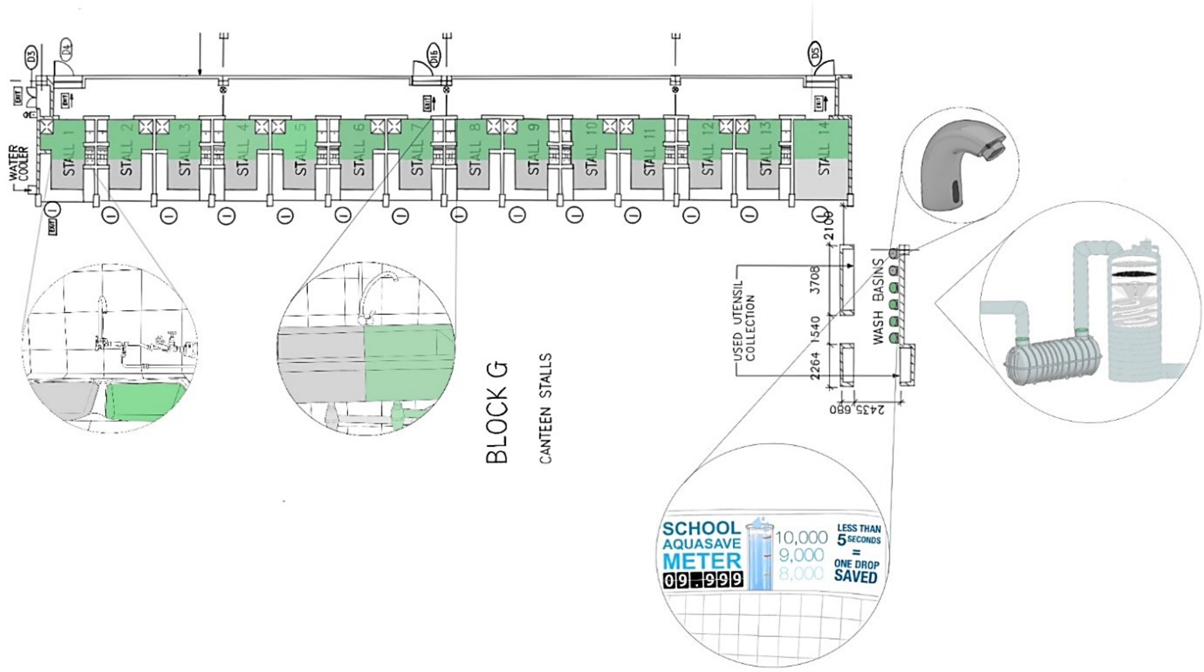
Standard / Sample	Water Quality Test 1							
	Odour	Colour (in hazen units)	pH	Turbidity / NTU	DO / mg / ℓ	DO after 5 days / mg / ℓ	E.coli / 5ml	E.coli / 100ml
	Non offensive	<15	6-9	<2	≧2	<5	Non-detectable	Non-detectable
Washing Fruits & Vegetables	Non offensive	Slightly offensive	6.7	1.9	6	1	1	20
Washing Grains	Non offensive	Cloudy	7.2	20.0	6	2	3	60
Washing Meat	Slightly offensive	Cloudy and Bloody	6.7	13.3	9	1.5	10	200
Washing Processed food	Slightly offensive	Cloudy	7.0	20.0	4	0.5	19	380
Rinsing utensils	Non offensive	Clear	7.2	1.9	8	6	Non-detectable	Non-detectable
Soap with grease	Slightly offensive	Cloudy	6.6	20.0	7	2	>1000	>1000
Washing hands without soap	Non offensive	Clear	7.1	1.9	7	5	82	1640
Washing hands with soap	Non offensive	Slightly cloudy	7.3	1.9	7	2	239	4780

Standard / Sample	Water Quality Test 2							
	Odour	Colour (in hazen units)	pH	Turbidity / NTU	DO / mg / ℓ	DO after 5 days / mg / ℓ	E.coli / 5ml	E.coli / 100ml
	Non offensive	<15	6-9	<2	≧2	<5	Non-detectable	Non-detectable
Washing Fruits & Vegetables	Non offensive	Slightly offensive	6.7	1.9	8	5	0	0
Washing Grains	Non offensive	Cloudy	7.2	20.0	7	0	168	3360
Washing Meat	Slightly offensive	Cloudy and Bloody	6.7	19.4	6	0	10	200
Washing Processed food	Slightly offensive	Cloudy	7.0	11.0	6	0	19	380
Rinsing utensils	Non offensive	Clear	7.2	1.9	8	4	Non-detectable	Non-detectable
Soap with grease	Slightly offensive	Cloudy	6.6	20.0	6	1	>1000	>1000
Washing hands without soap	Non offensive	Clear	7.1	1.9	7	5	3	60
Washing hands with soap	Non offensive	Slightly cloudy	7.3	12.6	6	4	0	0

Standard / Sample	Water Quality Test							
	Odour	Colour (in hazen units)	pH	Turbidity / NTU	DO / mg / ℓ	DO after 5 days / mg / ℓ	E.coli / 5ml	E.coli / 100ml
	Non offensive	<15	6-9	<2	≧2	<5	Non-detectable	Non-detectable
Washing Fruits & Vegetables	✔	✔	✔	✔	✔	✔		
Washing Grains	✔	✔	✔		✔	✔		
Washing Meat		✔	✔		✔	✔		
Washing Processed food		✔	✔		✔	✔		
Rinsing utensils	✔	✔	✔	✔	✔		✔	✔
Soap with grease		✔	✔		✔	✔		
Washing hands without soap	✔	✔	✔	✔	✔			
Washing hands with soap	✔	✔	✔	✔	✔	✔		

ANNEX K

Overarching Blueprint of Water Efficient Canteen



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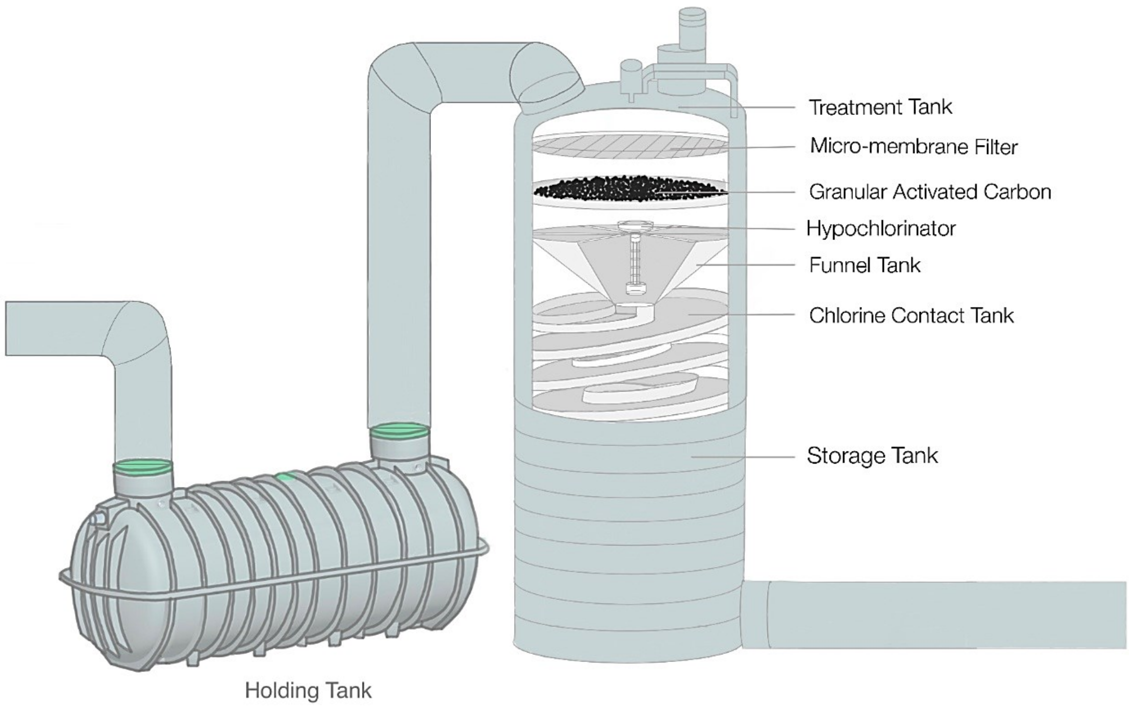
ANNEX L

Artistic Impression of Water Purification System (WPS)



<u>ANNEX M</u>

PUB Community Meter

ANNEX N

Artistic Representation of School Aquasave Meter (SAM)