Rainwater Harvesting

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Abstract

The problem at hand is that the school excessively spends water on watering plants, and does not take advantage of rainwater, a free and renewable source of water. This results in a lot of money going to waste, which can be used to improve or build other facilities. Thus, with reducing the school's expenditure on water for watering plants in mind, we set out on our project, to design and implement a working system, that not only can save costs by collecting and watering plants with rainwater, but can also reduce gardeners' workloads. Our proposed solution is a system which enables the school to easily collect and distribute rainwater in an area. Additionally, a core feature of our solution is that it is modular, which enables the school to modify and customise each module to fit the environment around it. There are many variables that can be changed, from the funnel that collects water, to the distribution system that waters the plants. After testing our design, we have managed to collect approximately 23 liters of water over 3 consecutive rainy days. This proves that our solution is effective in the collection of rainwater to be stored, and can reduce water costs for the school.

Introduction and Literature Review

From some preliminary research, it was found that Earth is experiencing extreme weather changes, and Singapore is not exempt (Ng, 2019). Singapore experiences heavy downpours on some days, and high temperatures on others. This irregularity may cause a stretch of hot days, bringing a rising need for the watering of plants.

The main problem that was identified is that water is being used excessively by the school for various reasons such as watering plants and for toilet facilities. Usually, rainwater flows out of the school from drains, and Hwa Chong imports water from external sources to water plants on hot days, which is not cost-effective. Plants can survive on rainwater (Elliott, 2008), so using imported filtered, clean water is not necessary. Rainwater collected can be directly used to water plants, without any processing. Thus, this problem can be solved by collecting rainwater, and the school can save money.

Furthermore, after interviewing one of the gardeners, it was found that in order to water any given patch of land, gardeners have to first connect the hose to a water tap, then carry the hose all the way to where they need to water, and turn on the tap. This is a tedious and time consuming process, which can be resolved by collecting rainwater, not only reducing the manpower required, but also the workload of the gardeners.

Singapore is located 1 degree north of the equator, and thus has a tropical climate (Hawksford, Weather and Climate in Singapore). Singapore receives 2342.2 mm of rainfall in an average year (National Environment Agency), which equates to 6.42mm on an average day. This shows that Singapore experiences high rainfall, so collecting rainwater is viable.

Some existing water collection systems may not be desirable as they are not modular. This means that it would be hard to integrate onto the school grounds, as they may require drilling and intensive construction to implement. These water collection systems are also not cost effective, as many require electricity to run. Furthermore, the mechanical and electrical parts require regular maintenance, and thus such systems are not sustainable in the long run.

This project aims to save costs of importing water to water plants, as well as reducing the workload of gardeners.

Prior to prototyping, research was conducted to find out what solutions were already in place to collect rainwater. First, one type of solution was the rain barrel. Water obtained from the roof's surface area is channeled through the gutter into the rain barrel, which acts as a water tank. (Poindexter & Jennifer, 2010). The rain barrel is cheap, environmentally-friendly, and easily obtainable. However, as seen in Figure 1.1, the barrel requires a downspout, a major flaw in its design. This is due to it needing to be installed under a roof, and it relying on the roof's surface area to collect water. If the roof were to not properly let rainwater flow into the downspout, the efficiency of the collection would be drastically reduced. Also, construction is required to install such a rainwater collection system, and thus will not be easy to set up, which is in contradiction to our easily implemented modular systems. Furthermore, it is not portable, and if not set up correctly, mosquitos could enter and proliferate, which would become a major problem, especially in Singapore. Mosquitoes can carry a multitude of diseases, such as dengue, Zika and malaria (CDC, 2016). This is already prevalent in Singapore, where there are up to 250 cases a day (NEA, 2020). Thus, it was decided that our solution would be able to keep mosquitoes from breeding, and also be easy to set up.

Figure 1.1 Rain Barrel

Another current solution in the market is a rainwater harvesting system used in urban areas, as shown in Figure 1.2. In such a system, rainwater is collected, usually from rooftops with large surface areas, which is then collected in a large water tank. Water is then channeled on demand through pipes, which flows through a filter, and finally reaches the area of distribution. The system in Fig 1.2 is efficient and effective as it can collect large amounts of rainwater. However, the system is reliant on mechanical equipment such as pumps, which will require regular maintenance. This equates to unnecessary manpower costs to ensure that the system is not failing. Also, integrating the tank with a distribution system will not be simple, and may require drilling, which defeats the purpose of an easy to set-up system.

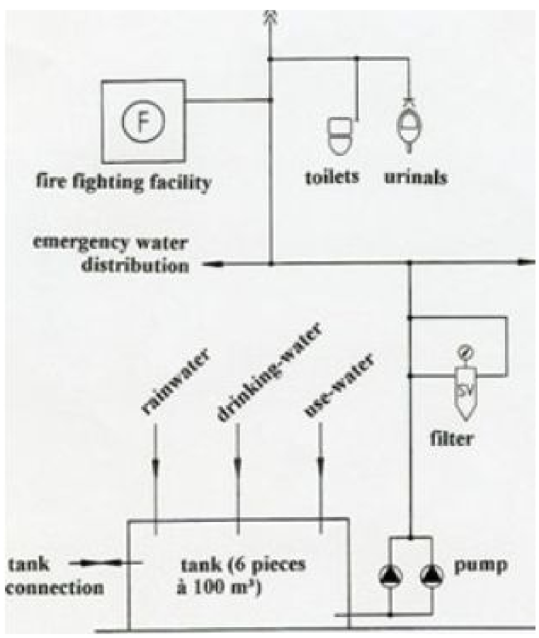

Fig 1.2 Rainwater collection system in urban areas(Centre for Science and Environment, 2012)

Proposed Solution

Our proposed solution consists of a collection system and a distribution system. The proposed system will save approximately $0.25 per month per module. This is with reference to PUB's potable water price of $4.06 per 1000 litre (PUB, 2020).

Collection system

The collection system needs to be able to collect sufficient water, and be able to store that water for an extended time. Additionally, it needs to prevent the proliferation of mosquitoes. The collection system involves a funnel for collection of rainwater, a recycled deionised water tank obtained from the chemistry laboratories, and mosquito netting fashioned out of laundry bags. The collection system is cheap, with the tank and mosquito netting easily recycled. Additionally, the funnel is extremely cheap, at a low cost of $2.50. The funnel can collect an average amount of 2 litres of water per day. The ease of building of the prototype, enables the product to be easily produced, allowing for multiple modules to be produced without much money or effort spent.

Figure 2.1 shows an 8 inch funnel which was used, which cost $2.50 from a hardware store at Kelantan Lane.

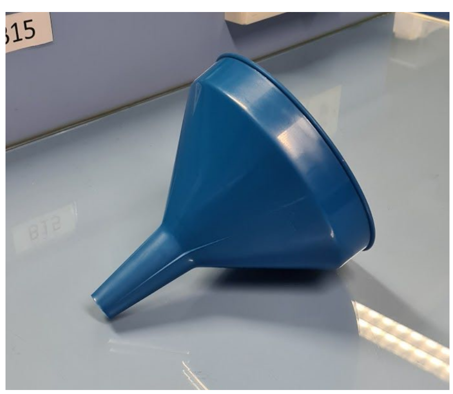

Figure 2.1

Figure 2.2 shows a 25 litre tank, normally used for storing deionised water in the chemistry laboratory. Additionally, the tap allows for semi automatic watering of plants. This particular tank was a little leaky, and thus not suitable for the chemistry lab. However, it is still perfectly good for our use case.

Figure 2.2

Figure 2.3 shows a laundry bag, which we fashioned a mosquito net out of. We found this to be a cheap and effective solution, without needing to buy specialized mosquito netting.

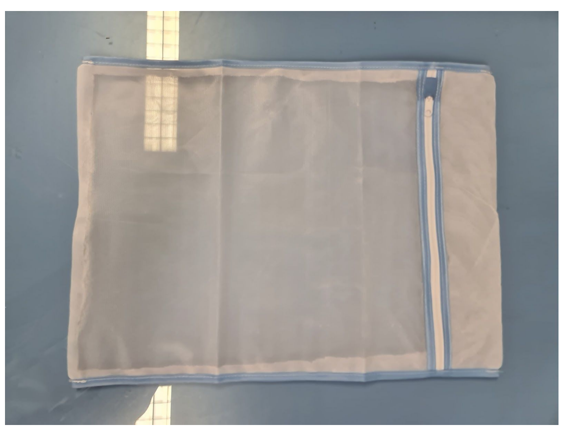

Figure 2.3

Figure 2.4 shows the completed prototype. The mosquito netting is placed at the mouth of the tank, and secured firmly using cable ties to the handles of the tank. The funnel is then placed on the mosquito netting, in the mouth of the tank.

Figure 2.4

Distribution System

The distribution system allows for the solution to water a larger area of water, and to water said area evenly. Additionally, this takes advantage of the tap of the tank available to use, to enable effective semi automatic watering of plants. The distribution system will be placed under the tap, at a tilted angle, allowing gravity to distribute the water. This is why we have chosen the site of implementation (Figure 2.5), as a slope gradient exists, removing the need for mechanical or electrical equipment to distribute the collected rainwater. This specific system is effective for the specific site of implementation (Figure 2.5), as one module placed in the center of the site will allow the entire site to be watered. The site is small enough for thorough watering with only a single module, and the chance of human activity is low, lowering the chance of accidental destruction.

Figure 2.5

This distribution system is more effective than current systems, as it does not require electricity to function, nor does it require preliminary construction. In comparison to the distribution system from Figure 1.2, our system does not require any piping, reducing costs for the school. The ease of access of the distribution system being at the site that requires watering also reduces the workload of the gardeners.

Figure 2.6 shows an unfinished prototype of the distribution system. As described above, a singular stream ends up spreading over a wider area due to the pen caps. This is proof of our concept.

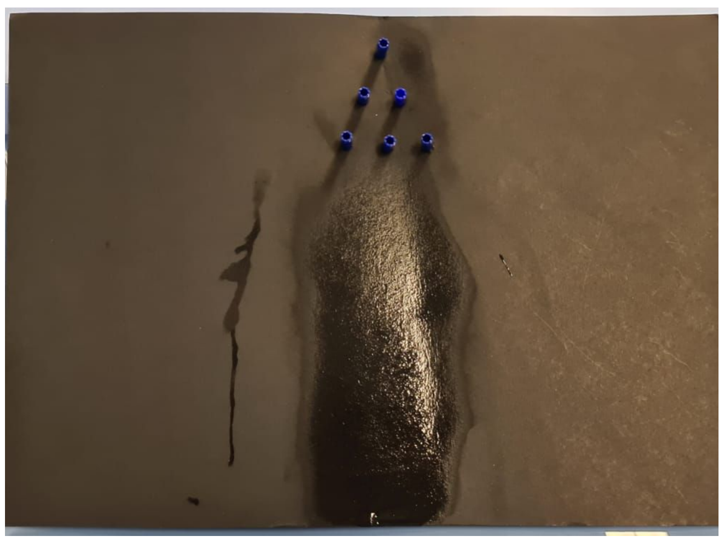

Figure 2.6

Figure 2.7 is a Blender 3D Model of the distribution system.

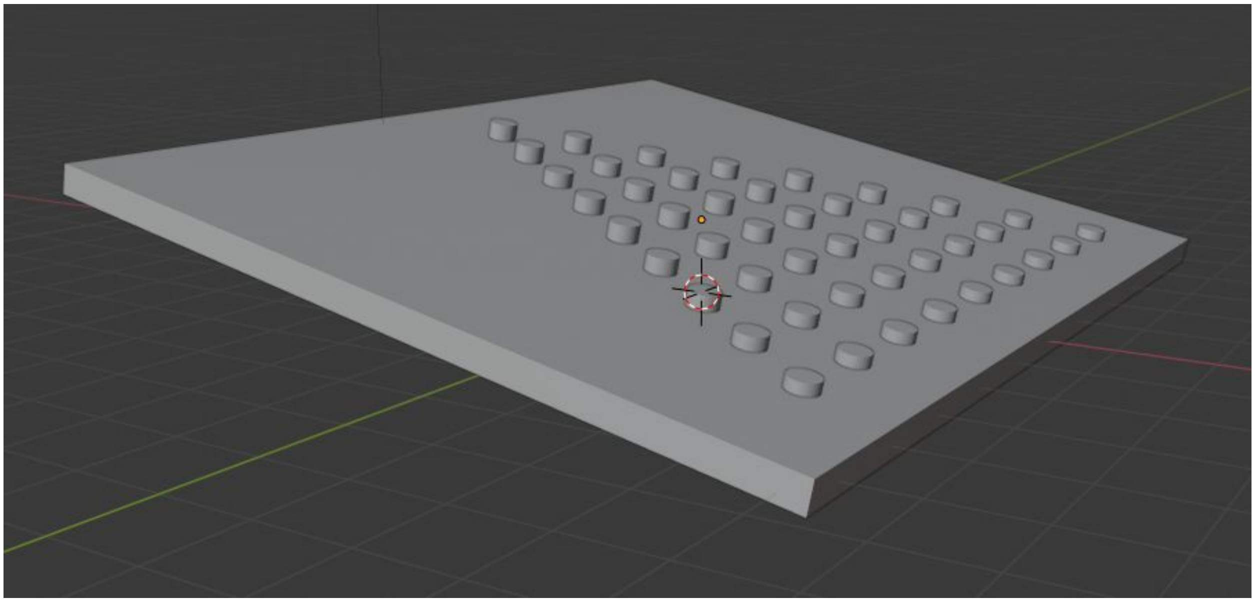

Figure 2.7

Future Work

More modules for different parts of the school would be implemented. A hole would be drilled in the side of the water tank, in case of overflow. The size of the funnel would be increased for a higher surface area and thus more rainwater collected.

Each module would be customised to fit each site of implementation, with the size of the funnel, distribution system, and concept of distribution system tailored to fit. This is to minimise costs while maximising efficiency.

In the long term, every module has to be briefly inspected daily, to ensure that the laundry bag serving as mosquito netting, has not been torn apart. Maintenance will also have to be done regularly on modules.

Citations

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