FEASIBILITY OF COLLECTING RAIN WATER AT NTU (NAYANG TECHNOLOGICAL UNIVERSITY)

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ABSTRACT

In Singapore, we have an annual rainfall of about 2250mm, but due to land constraints, there are insufficient rainwater catchment areas. As Singapore depends heavily on water, there is a continuous search for new water sources. One such source is roof water. The rooftops of the halls in NTU have a huge potential for rainwater collection. Our aim was to come up with a suitable rainwater filter system to utilize this untapped resource for non-potable uses. This filter aims at improving the acidity and the purity of the rainwater collected. The filtrate obtained from the prototype should be of a certain quality capable of storage for a period of time. A filter prototype was made from sand, activated carbon and sponge. The pH, conductivity and turbidity of the samples were tested and compared in an experiment. The results show that the filter improves the pH and the turbidity of the water, while the conductivity test was inconclusive. On the whole, we find that the filter succeeded in filtering off major components.

1. INTRODUCTION

1.1 Elixir of Life: Water

Water, the elixir of life, is needed by mankind and creatures alike. Its uses and applications have made life easier for us. Water is a very important basic need of humans. Although essential, freshwater is unevenly distributed. Only 2.5 of earth’s water is freshwater and almost three quarter of it is frozen in the ice caps. While most regions there is still enough water is meet everyone’s needs, it needs to be properly managed and used. In today’s world, much water is wasted or used inefficiently; often demand is growing faster than the supply can be replenished by nature. While competition over water resources can be a source of conflict, history has shown that shared water can also be a catalyst for cooperation. By 2025, it is estimated that about two thirds of the world’s population - about 5.5 billion people – will live in areas facing moderate to high water stress (United Nations, 2002).

In Singapore, our annual rainfall is about 2250mm but due to land constraints and competing demands for land use, only half of Singapore’s land is available as catchment areas. Knowing the importance of water to our thriving industries and growing population, Singapore has been trying to find ways to meet the increasing demand. Since 84 % of the urban population lives in high rise buildings, the roof of such structures have good potential to act as catchments to collect rain water and use it , preferably , for non-potable uses. Even as far back as 1986, PUB (Public Utilities Board of Singapore) has conducted experiments on rainwater collection on the roof tops of a number of HDB flats in the Redhill estate. In support of the nation's effort to fully utilize every source of water, NTU has also done some experimental research on the collection of rainwater from the main spine of NTU and to use the rainwater for non-portable purposes.

Though much research has been done on NTU's main campus, it has come to our attention from our research that not much has been focused on the hall of residence in NTU. We have noticed that the rooftop of halls have huge potential to act as catchment areas of rainwater. The hall of residence houses a large population of students who require significant amounts of water for their daily use. Thus we have decided to come up with a suitable rainwater filter system for non-potable uses in the halls. For our experimental filter, we aim to get a filtrate that is of a quality that should enable us to store it for a period of time before use.

2. LITERATURE REVIEW:

In recent years, more and more countries such as Thailand, Nepal, Philippines, Germany and Japan are beginning to carry out rainwater harvesting for different uses such as domestic and industrial usage. Different collection systems, filtration system and storage systems have been used in the different processes (United Nation Environment Programme or UNEP, n.d). More on these shall be discussed below.

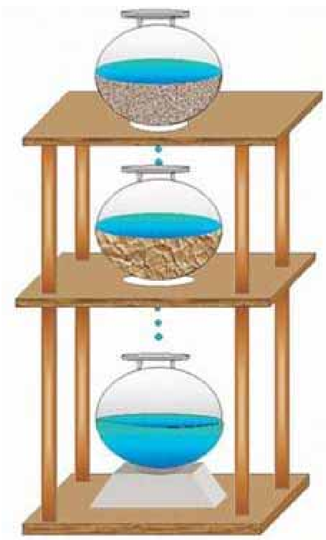
Several countries have started to collect rainwater for different uses. An example is Japan, who had adopted a rainwater collection system called the “Rojison” to collect rainwater for non-potable usages. Another example is Germany, who in October 1998, had undertaken a project in Berlin to collect rainwater at 19 large buildings, also for non-potable usage. Since 1989, Philippines have started on rain harvesting with the assistance of Canadian International Development Research Centre (IDRC). (UNEP, n.d)

2.1 Different types of Filtration Systems

Several types of filtration methods have been used worldwide, one of which is the Portable Reverse Osmosis Water Purifier. It involves a process whereby aqueous solution, under pressure, is passed through an appropriate membrane and withdrawing the membrane permeate at atmospheric pressure and temperature, in this case water.(Kadhim, Ismail & Jassim 2003).This device is able to produce 7 litres per hour from any type of water. It does not have any space constraint and only consumes very little power**.** The problem of this system, is that it will not be able to function properly if its reverse osmosis membrane is fouled due to the organic, biological and colloidal matter in the feed water (Isaias, 2001). The reverse osmosis system would thus require a filter membrane to aid in the removal of suspended particles before the water can go through to be purified by the reverse osmosis process. This system would also experience problems due to the start – stop cycles and partial load operations during periods of oscillating power supply. (Tzen, Morris 2003). The system is expensive which might prove to be a stumbling block.

Another type of filtration system used is the UV-protected granulated activated charcoal bed method, which uses charcoal and UV lights to sterilize the water. (Urban Water, 2000) states Charcoal attracts the bacteria onto its surface while the UV light kills the bacteria. The UV light also extends the life span of the charcoal. Third World academy of Science or TWAS (2002) claims that effectiveness of the charcoal increases when its surface area is increased. As such, powdered or granulated charcoals are used instead of charcoal lumps. Unlike other disinfectants, UV light does not leave any byproducts, which reduces the number of process need to finally clean the water. This method is a relatively inexpensive method and suitable for the needs of our project. However, we should consider using sunlight as the source of UV light as sunlight will make our project more cost effective.

One of the high technology water filtration methods in the world is TiO_2 photocatalysis method. It exposes the inexpensive and nontoxic TiO_2 to UV light to purify water. TiO_2, when subjected to UV light, produces free radicals that kill bacteria, fungi and viruses in a brief time (Chemosphere, 2003: 53). This TiO_2 is not used up in the purification process. Several improvements have made the TiO_2 photocatalysis method even simpler and more effective. One example is to shine sunlight instead of a UV light bulb. Past research has also show that the light absorption property of TiO_2 can be improved by adding small amounts of iron oxide (Fe2O3) (Third World academy of Science or TWAS, 2002). The above steps allow the coating to be used effectively for longer periods, hence reducing the maintenance cost. Although the start-up cost is relatively high, the water filtered is of high quality.



The next filtration system we looked into is the Mud-Pot Filtration method, which TWAS claimed homes in South-Asia are using. This filtration consists of a three-layer system requiring no electrical power. TWAS commented that although this kind of filtration is cheap and produce relatively clean water, the collection rate is slow and the substances used in the filtration needs to be changed frequently (TWAS, 2002). As such, it can be seen that it is quite troublesome to maintain the setup, and that it may takes too long for the water to be filtered for use.

Solar disinfection is another relatively cheap method (SODIS). EAWAG/SANDEC stated that SODIS improves the quality of drinking water. This technology uses UV radiation to kills microorganisms in the water collected in either fully transparent or half-black containers. Studies carried out in two villages in Thailand shows significant decrease in gastrointestinal disorder cases. Another test in November 2002 in Nepal showed that in high altitude areas, half-black containers serve better in removing microorganisms than fully transparent ones. To-date, the EAWAG/SANDEC has carried out SODIS projects in Latin America, Indonesia, Thailand, Sri Lanka, Uzbekistan, Kenya and Nepal. (EAWAG/SANDEC, n.d). This method is relatively cheap, but will only remove the microorganisms from the water. Additional steps have to be taken to remove the impurities in the water.

The last method discussed is the electrochemical activation method. In this method, electrical means instead of light is used for purification. When current is passed into the system, all organic and biological substances in the rainwater are oxidized thus decontaminating the water. Besides purifying the water, this system is able to produce chemicals like hydrogen peroxide, a powerful oxidizing agent capable of preventing bacterial growth in the water during storage. (Grimm, Bessarabov & Sanderson, 1998) Although water purification by electrical means is already on the market, they are rather expensive and furthermore the quality of the filtrate is above our requirement.

After reviewing the above filtration methods, we have decided to incorporate parts of the mud-pot filtration and charcoal UV filtration system to come up with a single feasible filter model.

3. MATERIALS

The filter was developed for non- potable uses. It was intended for usage in the halls in NTU with minimal maintenance and cost. It was designed to improve the pH, turbidity and to remove impurities. Its design was based on the mud-pot and activated carbon filter systems that have been studied.

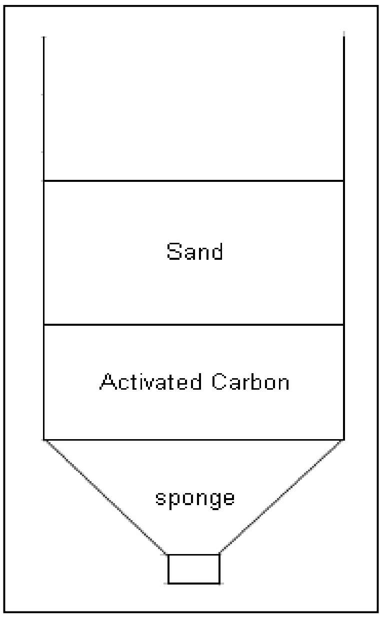


Figure 1: Filter

The filter consists of a layer of sand, activated carbon and sponge. These substances were particularly placed in a certain order (Figure 1). The sand filters off larger solid particles present in the rainwater. The activated carbon contains zeolite which has a highly porous structure, enabling it to capture very fine particles and adsorbs heavy metals and ammonium. It also absorbs some organic contaminants and undesirable odours. Lastly the sponge further filters off any more particles remaining it the water. The sponge further acts as a stopper, preventing the sand and the activated carbon to go through. Besides these filtering layers, the punctured hole at the bottle cap also controls the rate of flow of the water, enabling more time for the water to go through the filtering layers.

The filtrate obtained from the filter system would then be experimented on to determine its quality.

4. METHODS

The aim was to come up with a suitable rain water filter system for non potable uses in the halls. The filtrate obtained has to be of certain acceptable quality. After reviewing several filtration methods, we came up with a filter prototype. To test the effectiveness of the filter, rainwater was collected and subsequently, several tests were done on the rainwater and the filtrate in the laboratory.

Firstly, a 1.5 litres water bottle was obtained. The empty bottle was thoroughly cleaned to ensure that there would be no contamination to the filters. A small puncture mark was made to the cap of the bottle to control the rate of flow of the rainwater to ensure sufficient time was given for the water to flow through the system. Next, the base of the bottle was cut off and the sponge, followed by the activated carbon and then the fine grained sand were placed into the bottle. (See Figure 1)

Rainwater was collected on 19 March 2004 from the runoff of the rooftop of Hall of Residence 6. About 2 litres of rainwater was collected and about half of it was passed through the filter system. Both the filtrate and the rainwater were stored separately in clean empty bottles.

On 24 March 2004, the samples were brought to Eutech Instrument Laboratory for testing. The aim of these tests was to measure the pH, conductivity and turbidity of the samples. Electronic pH, conductivity and turbidity indicators (figure 2) were used for the tests.

Figure 2 : Various Indicators

Conductivity indicator | pH indicator | Turbidity indicator

The first test conducted was the conductivity Test, which indicates how well a sample can conduct electricity. The better the sample can conduct electricity, the more ions there are in the sample. The unit of measurement is in Siemens(S). The samples were poured into 2 separate clean beakers. The electrodes of the conductivity indicator were submerged into the beakers containing the samples and the readings were recorded. A total of 3 readings were taken.

The next test conducted was the pH test, which indicates how acidic a sample is. The unit of measurement is in pH in which the values vary from 1-14. The lower the values, the more acidic it is, with pH value 7 as the neutral point. The samples were poured into 2 separate clean beakers. The electrodes of the pH indicator were then submerged into the beaker containing the samples and the readings were recorded. A total of 3 readings were taken.

Lastly, the turbidity test was conducted, which measures how clear or how much solid impurities a sample has. The unit of measurement is in nephelometric turbidity unit (ntu). The higher the ntu value, the higher the amount of solid impurities present in the sample. 2 testing 30 ml glass bottles were used to contain the filtrate and the rain water. These bottles were placed into the turbidity test unit and light was passed through the samples. The intensity of the light was then measured and total of 7 readings were taken.

From the results obtained for the tests, the quality of the filtrate was compared with that of rainwater.

5. RESULTS AND DISCUSSIONS

Rainwater in Singapore is relatively acidic (Appan, 1999) as it contains several unpleasant chemical compositions. As such, our filtration system aims at removing some of these chemical compositions, and reducing the acidity of the water. On top of that, as the rainwater is collected from the rooftop runoff, many impurities are present in the sample collected. Hence our filtration system also aims at purifying the water by removing most of these impurities. Below are the results collected from the experiments conducted.

5.1 CONDUCTIVITY

The conductivity test is done to test the number of ions present in the samples tested.

Table 1 : Conductivity of Samples

Samples	Rainwater at 27.9^{o}C	Filtered Rainwater 27.8^{o}C	Tap water
Sample 1	64.0 µS	292.0 µS	104.6 µS
Sample 2	62.2 µS	290.0 µS	N.A
Sample 3	62.6 µS	292.0 µS	N.A
Average	62.9 µS	291.3 µS	N.A

Percentage increase in conductivity = (291.3 - 62.9) / 62.9

= 363.12 %

Percentage difference in conductivity between tap water and rainwater

= (104.6 - 62.9) / 62.9

= 66.30 %

As it can be seen from the results (table 1), the conductivity of the rainwater has increased by about three and a half times after going through the filtering system. This shows that the number of ions presents in the rainwater sample increased after the filtration process. This effect could be due to the activated carbon filter used in the filter system. In the carbon filter used, various chemicals were added to aid the filtering process. For example, it contains zeolite, which helps in the removal of heavy metals. When the metals are removed, ions could be freed up resulting in an increased in conductivity.

When the tap water is tested for its conductivity, it has a value of 104.6 µS, which is about 66% higher value as compared with the average value of 62.9 µS for the rainwater sample. This shows that having higher amount of ions in the filtered water does not mean a drop in the water quality. Hence it is concluded that the conductivity test is not an accurate test to use for testing of the water quality of the samples.

5.2 pH VALUES

The pH test is done to test the acidity of the samples tested.

Table 2 : PH Values of Samples

Samples	**Rainwater at 27.9^{o}C**	**Filtered Rainwater 27.8^{o}C**
Sample 1	4.95	6.38
Sample 2	4.99	6.25
Sample 3	5.02	6.33
Average	4.99	6.32

Percentage increase in PH values = (6.32 – 4.99) / 4.99

= 26.65 %

As seen from the table 2, the pH values of the samples increase towards the neutral value of 7 after filtering. This shows that after the filtering process, the sample becomes less acidic. This removal of acidity is most likely done by the activated carbon filter. This is a very significant result as it shows our filter system is able to reduce the acidity content of the water, hence letting it to have a pH value closer to pH 7 of pure water.

5.3 TURBIDITY

Turbidity is a measure of how clear the sample is. It tests the amount of solid impurities in the samples. With increased impurities, the turbidity value would be higher.

Table 3 : Turbidity of Samples

Samples	**Rainwater at 27.9^{o}C**	**Filtered Rainwater 27.8^{o}C**
Sample 1	2.83 ntu	1.95 ntu
Sample 2	2.88 ntu	1.93 ntu
Sample 3	2.71 ntu	1.92 ntu
Sample 4	2.71 ntu	1.91 ntu
Sample 5	2.75 ntu	1.90 ntu
Sample 6	2.76 ntu	1.89 ntu
Average	2.77 ntu	1.92 ntu

Percentage decrease in turbidity = (2.77 – 1.92) / 2.77

= 30.69 %

As seen from table 3, there was a decrease of about 30% in the turbidity value after the rainwater sample was passed through the filtration system. This shows that the impurities in the sample decreased after the filtration process, implying a decreased in the amount of solid suspension. The reason is most likely due to the sand and the activated carbon, which are capable of removing fine particles in the samples. The lower value of turbidity of the filtrate means that the amount of solid suspension in the water is less than that in the rainwater. This is an important finding as this shows the filtrate is of a better quality.

The turbidity of tap water tested is 0.24 ntu as compared to the average value of about 1.92 ntu of the filtered samples.

Despite the negative result in the conductivity test, it can be seen that the filtration system proposed indeed fulfill the aim in removing some impurities and reducing the acidity of the rainwater to a certain extent. This improvement definitely aids in its usage for non-potable purposes.

6. CONCLUSION

Water is the source of life and it is mankind's most precious commodity. However the availability of water is decreasing and the treatment of existing water resources is therefore essential. Rainwater is one such important source and the aim of our project was to come up with a suitable rainwater filter system which is able to give a quality filtrate, for non-potable uses in the halls of NTU.

From our results, we concluded that the system we have come up with succeeded in filtering off major components. Simple and inexpensive materials were bought to construct the filter system. After the rainwater was collected and processed, experiments were conducted in the lab to test and compare the quality of the water samples. The results obtained showed that the pH and turbidity of the filtrate improved significantly. However the conductivity test was inconclusive as it was unable to tell us what ions were present in the sample. The improved quality of the rainwater meant that the filtrate is suited for non-potable use. Furthermore the improved quality discourages algae and bacteria growth and increases storage life.

Although the experimental results showed that there was improvements in the filtrate, certain parameters pertaining to the test of the filtrate was left out due to the lack of appropriate equipment and the luxury of time. Parameters like the sulphate and nitrate content were not tested. Testing for sulphate and nitrate ions could further illustrate the purity of the water and give us a better view of how to further improve our filter system. The main feature of our filter system is the activated carbon but it loses its effectiveness after some time. Therefore it would have been better to use a better grade of carbon layer and test conducted could have been done over a period of time in order to know the system's effectiveness over some time. Future studies could be done to look into the maintenance of the filter system so as to improve its function.

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