UBC Social Ecological Economic Development Studies (SEEDS) Student Report

An Investigation into Filtration of the Cistern-Collected Rainwater for the new UBC Student Union Building

Peter Yeung

Teresa Chu

Andy Khoo

Jerry Chang

University of British Columbia

APSC 262

April 1, 2011

An Investigation into Filtration of the Cistern-Collected Rainwater for the new UBC Student Union Building

Peter Yeung
Teresa Chu
Andy Khoo
Jerry Chang

April 1, 2011
APSC 262: Technology and Society II
Dr. Akram Alfantazi

Abstract

The new Student Union Building, to be completed in 2014, at the Vancouver campus of University of British Columbia will collect rainwater through the rooftop for non-potable use in the building. A study is conducted to investigate on a possible water treatment process after the rainwater has been collected. The proposed design includes filtration, disinfection, and overflow and back-flow preventions. In the water treatment system, the collected rainwater first runs through a filter to remove the large pathogens. The biosand filter is used to filter the water and is capable of eliminating greater than 90% of the coliforms. The biosand filter is chosen primarily due to its low impact on the environment, zero energy consumption during operation, and inexpensive costs. Then, the rainwater is disinfected by ultraviolet light to ensure all bacteria are removed. The system also contains sensor and control valves in the case of water overflow or backflow.

Both the biosand filter and the ultraviolet disinfection methods have low impact on the environment and present no significant harm to humans during operation. The cost of biosand filter is extremely low to purchase, to maintain and to operate. Although the ultraviolet system is more expensive, it operates at low cost and will balance the cost after a period of usage. The proposed system is recommended based on the investigation performed, as each component has been evaluated to be affordable and sustainable.

Table of Contents

List of Illustrations

Glossary

Biosand	Technological adaption of the centuries old slow sand filtration process
Chlorination	A process in which chlorine is added into water as a disinfectant
E.Coli	A common type of bacteria live in the intestines of human or animal
Eukaryotic microorganisms	Microorganisms that has complex structure and are not easily manipulated by their environments
Metal Membrane	Utilizes pressure to force the water to pass through membrane of very small pore sizes
Microorganisms	Microscopic living organisms such as parasites, bacteria, and viruses
Nucleic Acid	DNA of a substance
Protists	A harmful bacteria that is responsible for malaria and sleeping illness disease
Ultraviolet	Electromagnetic radiation travelling in wavelengths in all directions from its source

List of Abbreviations

UBC	University of British Columbia
SUB	Student Union Building
THMs	Trihalomethanes
E.Coli	Escherichia Coli
PPM	Parts per million
UV	Ultraviolet
UVT	Ultraviolet Transmission Percentage

1.0 INTRODUCTION

The new Student Union Building at the University of British Columbia is currently in the design process. It is envisioned to become the most sustainable building on campus and an icon of green buildings around the world. One of the many sustainable features of the new SUB is that rainwater will be collected on the rooftop and used for non-potable use inside the building, such as cleaning, irrigation and toilet flushing. Since the rainwater is used to irrigate for gardens that produce food, the rainwater collected must be treated prior to usage. This report focuses on the water treatment process after the rainwater has been collected. The proposed design includes filtration, disinfection and overflow and back-flow preventions.

In the water treatment system, the collected rainwater first runs through a filter to remove the large pathogens. The metal membrane filter and the biosand filter are discussed, but with the latter in more details. Then, the rainwater need to be disinfected to ensure all bacteria are removed. Two methods of disinfection, chlorination and ultraviolet, are compared and analyzed. In addition, overflow and back-flow prevention designs are introduced to the system for the variable monthly rainfall amount. The report will investigate on various filtration, disinfection and prevention methods and provide recommendations based upon the triple bottom line analysis for each method.

2.0 FILTRATION

Although the quality of rainwater in Vancouver is considerably clean, pathogens can still exist in the water, especially during the collection process on the rooftop. Table 1 [1] shows the rainwater quality sampled and the water quality standards for agricultural water in Canada are found in Table 2 [2].

Table 1: Specifications of Rainwater

	Rainwater
pH	7.41
EC (μS/cm^2)	187.1
Turbidity (NTU)	4.76
Color	24
COD (mg/L)	12.6
Particle count (2–15 μm)	2570
Total count (mL^{-1})	49
Total coliform (MPN/100 mL)	>2419

Source: R.H. Kim, S *et al.* "Reuse of greywater and rainwater using fiber filter media and metal membrane."

Table 2: Water Quality Standard for Pathogens

Table 1 WATER QUALITY STANDARD FOR PATHOGENS		
Water Use	**E. coli**	**Fecal Coliforms**
Irrigation of crops eaten raw	< 77 cfu/100ml	< 200 cfu/100 ml
Irrigation general	< 1000 cfu/100ml	< 1000 cfu/100ml
Crop Washing	0 cfu/100ml	0 cfu/100ml

Source: BC Ministry of Water, Land and Air Protection / Health Canada

Source: www.agf.gov.bc.ca/resmgmt/publist/500Series/512000-3.pdf

Since the natural rainwater does not qualify to be used directly, water treatment is necessary. The filtration stage in the water treatment process is discussed in this section.

2.1 METAL MEMBRANE FILTER

A common filtration method is the metal membrane filter, which results in high quality filtered water. The metal membrane filter utilizes pressure to force the water to pass through membrane of very small pore sizes. The membrane is able to reject particles of 0.2~5 microns, and thus high percentage of elimination of bacteria, micro-organisms, metals, and parasites. Although the metal membrane filter is very effective in water treatment, it also requires expensive parts. The filter would need the metal membrane itself, a pressure pump, filter vessel and stand. Also, the filter will require power to operate the pressure pump and backwashing during maintenance, which results in higher cost and more energy consumption [1]. Thus, the metal membrane filter is not the ideal solution for filtering. The next section explores a more economic alternative filtration method.

Figure 1: Metal Membrane Filter

Source: http://www.p-wholesale.com/cn-pro/19/738to1/microporous-filter-661356.html

2.2 BIOSAND FILTER

The traditional slow sand filters have been used for water treatment for almost 200 years and a modified version, the biosand filter, has been invented in the 1990s [3]. In this section, the biosand filter is investigated in details and its suitability for the new SUB is evaluated.

2.2.1 Structure

A typical biosand filter is presented in figure 2 [3].

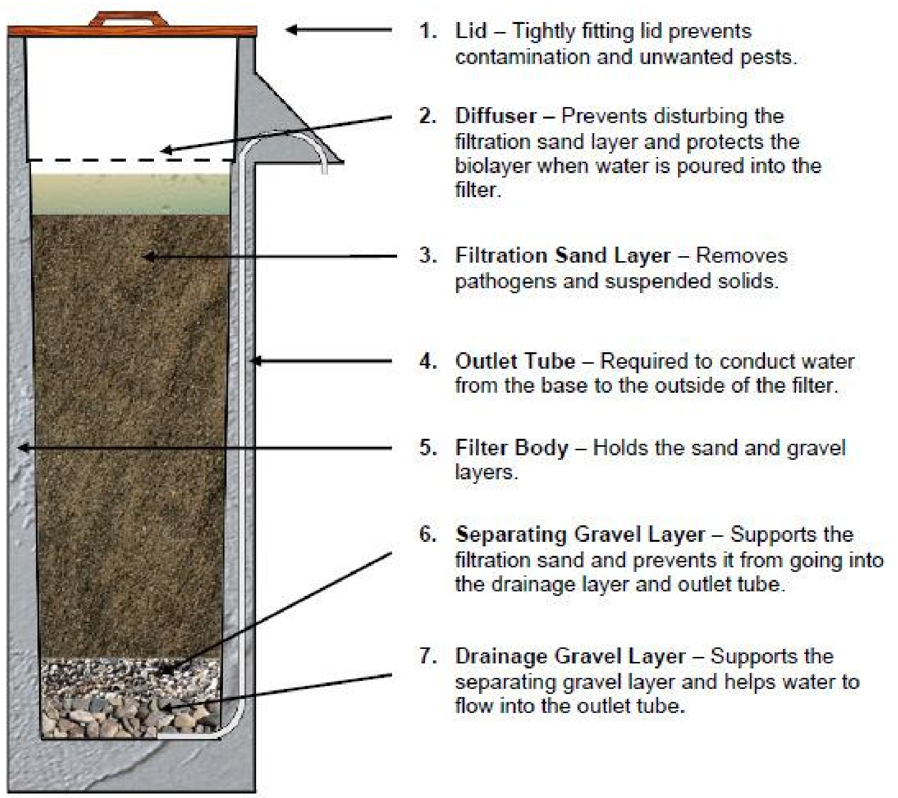

Figure 2: Simple Biosand Filter Layout

Source: http://www.cawst.org/en/resources/pubs/file/43-pi-for-bsf-manual-complete-english

The filter body is a container made out of usually concrete or plastic. The container is filled with mostly fine grains of sand and some gravel at the very bottom. The bottom of the container has an outlet tube which allows filtered water to flow out. A simple lid covers the top of the container to protect the filter from contamination.

Crushed rocks are the ideal filtration sand as it has various grain sizes, which is required for the filter to function properly. River sand and beach sand may also be used, but it should all be disinfected and properly treated to eliminate organic materials, salt, and other contaminants before use. For any sand type used, the sand size should be approximately 0.7mm in diameter to balance the quality of filtered water and the flow rate.

2.2.2 Operation and Specifications

The principle of operation of the biosand filter is that it contains very fine grains of sand, which collects particles and bacteria as water passes through the sand bed. The bacteria and micro-organism collected are usually trapped at the upper layer of the sand, which forms a biological zone. These micro-organisms then form a food chain and eliminate pathogens during the filtering process. The clean water that passes through the sand layer then flows out naturally from the outlet tube.

Biosand filters have different versions and they may be customized in size. For a typical version 10.0 biosand filter of 12 litre in reservoir volume, the recommended filter loading rate is no more than 400 litres/hour/m^2. The average monthly rainfall in Vancouver is 93.1 litres/m^2, which is within the limit. The flow rate produced is approximately 24 litres/hour, and may vary for different chosen sand types. Depending on the area of the rainwater collector on the rooftop, the number of biosand filters to be installed can be varied.

2.2.3 Biological Layer

The biological layer will take around 30 days to develop, and water quality will improve as it grows. Without the biological layer, the filter is only capable of eliminating 30-70% of the pathogens, but with the biological layer fully grown, it is able to eliminate more than 90%.

It is also crucial to have constant water flow so that the food chain in the biological layer can be sustained. The recommended pause period, which means no water is flowing through, is 1 hour to 48 hours. If the pause period is extended for too long, the micro-organisms in the biological layer may slowly deteriorate due to starvation.

2.2.4 Effectiveness

Field and laboratory researches have been conducted on the biosand filter, and the results are impressive. In a test lab, where the biosand filter is properly installed and the biological layer is well developed, it is capable of eliminating 95-98% of E. Coli, and 80-90% viruses reduction. In the field, the average E. Coli reduction is approximately 90%. The lower percentage in the field studies may be due to some improper operations of the filter. As the filter is most commonly used in developing countries to obtain drinking water, the filtered water quality is adequate to be used for irrigation in the new SUB. In the following table, the effectiveness of the filter for treating various pathogens in water is shown in Table 3 [4].

Table 3: Effectiveness of Treating Pathogens in Water

	Bacteria	Viruses	Protozoa	Helminths	Turbidity	Iron
Laboratory	Up to 96.5%[1,2]	70 to >99%[3]	>99.9%[4]	Up to 100%[5]	95% <1 NTU[1]	Not available
Field	87.9 to 98.5%[6,7]	Not available	Not available	Up to 100%[5]	85%[7]	90-95%[8]

1 Buzunis (1995)
2 Baumgartner (2006)
3 Elliott et al. (2008)
4 Palmateer et al. (1997)
5 Not researched. However, helminths are too large to pass between the sand, up to 100% removal efficiency is assumed
6 Earwaker (2006)
7 Duke & Baker (2005)
8 Ngai et al. (2004)

Source: http://www.cawst.org/en/resources/pubs/file/41-field-and-lab-testing-for-bsf

2.2.5 Maintenance

The maintenance required for the biosand filter is simple. The filter container, lid, and outlet tube should be cleaned on a regular basis. After constant usage for a period of time, the flow rate will decrease as excessive solids are trapped in the upper sand layer. When the flow rate has become intolerably slow, the filter can be cleaned using the swirl and dump method. The swirl and dump method is simply providing a stir in the upper sand layer and then removing the resulting dirty water. This process may damage the biological layer slightly, but it will rebuild after a few more usage.

2.3 TRIPLE BOTTOM LINE ANALYSIS

2.3.1 Economical

The biosand filter is simple to construct and uses materials that are abundant locally, thus the capital cost is extremely low, usually ranging from $12~30 per unit. The maintenance cost is also low and the most expensive part would be to hire trained staff to perform regular cleaning. Table 4 [5] shows the economical comparison of the metal membrane and the biosand filter.

Table 4: Economical Cost

Filter	Capital	Operation	Maintenance	Total(1st year)
Biosand Filter	$12~30	$0	$200	$250
Metal Membrane Filter	$6000	$500	$500	$7000

Source: http://www.sterlitech.com/membrane-disc-filters.html

2.3.2 Environmental

The materials used to construct the biosand filter are all environmentally friendly and produces no emissions. During the operation, the water flows through the sand layer due to gravity, thus has zero power consumption. The sand grains do not require replacement, and can be used permanently with regular cleaning. Also, the biosand water filters have a long life span of more than 30 years for concrete containers, and more than 10 years for plastic containers. Throughout the life cycle of the biosand filter, minimal waste will be created and it is extremely sustainable.

2.3.3 Social

Local businesses may also benefit as the school may hire entrepreneurs to construct and sell the biosand filters. Also, the maintenance required will create job opportunities in the new SUB.

3.0 DISINFECTION

Biosand filtration method has its advantages to filter out microorganisms, but there is still a possibility that harmful substances may exit past it. Since the rainwater is collected through the roof, there is a very high chance that the water collected is contaminated with animal droppings, which could contain bacteria like E.coli. Thus it is necessary to disinfect the water from bacteria and viruses. Two different methods of rainwater disinfection most suitable for the new SUB will be investigated in this section.

3.1 CHLORINATION

Chlorination is commonly used by many countries like the United States, Canada as well as other European countries. Rainwater usually contains dust, pathogenic bacteria and viruses, and heavy metals; therefore, disinfecting the contaminated rainwater is crucial because the water will be used for multiple reasons including flushing the toilet in the SUB and watering the rooftop garden. Chlorine can reduce and eliminate microorganisms like viruses and bacteria in the contaminated rainwater that would harm the human body.[10] Chlorine used to treat water comes in 3 different forms – gas, liquid chlorine, and dry chlorine. According to HealthLink BC, water should contain 2 parts per million (ppm) of chlorine.[12] Refer to Table 5 for the water and household ratio to produce water with 2 ppm chlorine. This portion of the report will investigate the environmental, economic and social aspect of chlorination.

Table 5: Water and household bleach ratio

Gallons of water to disinfect (equivalent shown in brackets)	**Amount of household bleach (5%) to add ***
1 *gal.* (4.5 *litres*)	2 drops (0.18 *mL*)
2 1/5 *gal.* (10 *litres*)	5 drops (0.4 *mL*)
5 *gal.* (23 *litres*)	11 drops (0.9 *mL*)
10 *gal.* (45 *litres*)	22 drops (1.8 *mL*)
22 *gal.* (100 *litres*)	3/4 teaspoon (4 *mL*)
45 *gal.* (205 *litres*)	1 1/2 teaspoons (8 *mL*)
50 *gal.* (230 *litres*)	1 3/4 teaspoons (9 *mL*)
100 *gal.* (450 *litres*)	3 1/2 teaspoons (18 *mL*)
220 *gal.* (1000 *litres*)	8 teaspoons (40 *mL*)
500 *gal.* (2200 *litres*)	6 tablespoons (90 *mL*)
1000 *gal.* (4550 *litres*)	6 1/2 ounces or 12 tablespoons (180 *mL*)

Source: http://www.healthlinkbc.ca/healthfiles/hfile49b.stm

3.1.1 Environmental Aspect

Water with added chlorine itself will not have a great effect on the environmental, since only 2 ppm of chlorine is present in the water, which is only about 0.0002 percent. [12] However, the chlorine used to disinfect the water should be properly stored. Accidental spill or release of chlorine can pollute the environment and can harm both human and animals when inhaled. Similarly, accidental spill of chlorine will increase the risk of contamination of rivers and streams, thus affecting health of the aquatic wildlife.

3.1.2 Economic Aspect

Many countries including Canada use chlorination as the primary disinfection method in the municipal water treatment facilities due to the low cost. While chlorine itself is cheap, many other factors have to be considered before implementing this method for the new UBC SUB. One factor is that chlorination equipment will need to be installed in the SUB. Refer to table 3.2 for the capital cost comparing chlorine gas and dry chlorine chlorination systems. Another factor that should be taken into consideration is the labour and training cost spent on maintenance of the system.

Table 6: Capital cost of Chlorination Systems in dollars ($)

Item	Gas Chlorination	Hypochlorite Tablets
Equipment	10482	875
Installation	1516	150
Building	10000	-
Total	21999	1020

Source: http://www.oas.org/dsd/publications/unit/oea59e/ch23.htm

3.1.3 Social Aspect

A major concern of using chlorination as a method to disinfect water is the by-product. When chlorine reacts with the organic matters present in the water, a kind of DBP called trihalomethanes (THMs) will be produced. Experts believe that high levels of THMs will increase the risk of bladder and colon cancer. In addition, pregnant women who drank large amount of tap water, which contains THMs, will also have a greater risk of miscarriage. Health Canada has established a guideline for THMs to be less than 0.1 grams per litre and states that cancer risk over a lifetime at that amount is extremely low.

[8] Another social aspect of utilizing chlorination method is the increase of employment. Operation and maintenance of the chlorination system would require UBC to hire additional staffs with particular training and knowledge in chlorination water treatment.

3.2 ULTRAVIOLET SYSTEM

Ultraviolet light is an electromagnetic radiation with wavelength shorter than the visible light. Its UV radiation can alter the nucleic acid (DNA) of bacteria, parasites, and viruses, so they become inactive and unable to multiply. [13] However, the water must be clear of any visible particles in order to maximize the ultraviolet system filtration system. Nevertheless, there is a slight chance of protists because they can survive under high UV doses, but they can be sterilized under low doses. Furthermore, the disinfected water should not be stored long because there is still a possibility of algae and other pathogens' formation. The UVT is a measurement of the percentage of transmittance of UV light, and is a good indicator for the percentage of effectiveness of UV lamps. The rates of UV disinfection are: UVT > 95% is excellent, UVT > 85% is good, and UVT > 75% is Fair. Even though most UV manufactures suggest that UVT > 75% is good enough, for the UBC new Sub design, it would be best to keep the UVT at least above 85% to ensure the safety of the water.[14]

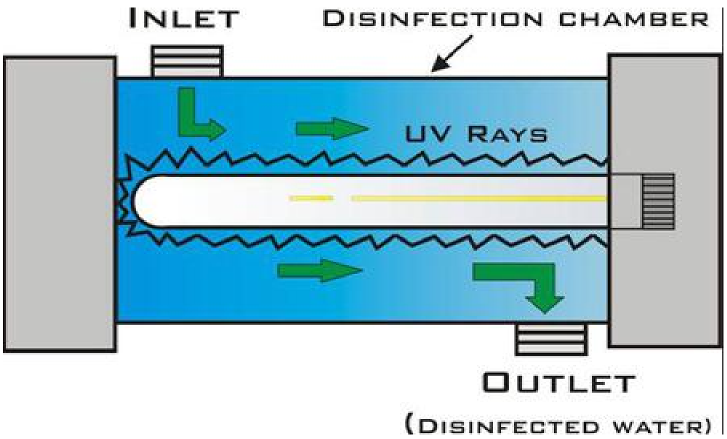

Figure 3: Simple design of ultraviolet system
Source: http://www4.agr.gc.ca/AAFC-AAC/display afficher.do?id=12414754121 60&lang=eng

One of the most outstanding features that this ultraviolet system has is that the water is chemical free and the system is low maintenance. However, nothing is removed from the water, the harmful particles will only be altered in a way that is safe to consume. In addition, installing the system may be expensive initially, but in the long run, it would actually save money since it does not constantly need renewal of its equipments.

3.2.1 UV System Types

The UV doses are defined as UV intensity multiplied by time. There are two types of UV systems [15]:

Class A systems are designed to inactivate and/or remove microorganisms. Most companies and manufactures believe that this system alone is enough to alter the nucleic acid (DNA) of bacteria, viruses, and parasites using its high dose of UV radiation. (30 to 40 mj/cm2) Therefore, almost all the ultraviolet systems built in companies or household appliances implement their designs to fit only this type.

Class B is most commonly used for bactericidal treatment, not for disinfecting the water. Usually this system is used as an additional feature or attachment to another filtering system, but not all companies like to add this additional feature. The primary reason is the cost of manufacturing. Since many companies believe that class A system is enough for sterilizing the harmful substances, they feel it is unnecessary to add another class B system. Unfortunately, through experimentation and research, scientist believes that even such high UV doses are not enough to eliminate all dangerous particles. For example, the protists are a group of eukaryotic microorganisms that have complex structures and can survive in almost any environment. Furthermore, the two most deadly protists are Kinetoplastids and Apicomplexa because they can cause series human diseases such as malaria and sleeping sickness. Since the UV dose (16 mJ/cm^2) is a lot smaller than class A system, they can be used to sterilize the protists; thus, eliminating another harmful particle in infected water.

3.2.2 The Operations of Ultraviolet System

Ultraviolet light is defined as electromagnetic radiation travelling in wavelengths in all directions from its source (lamp/bulb) with various ranges from 200 to 390 nanometers (nm).

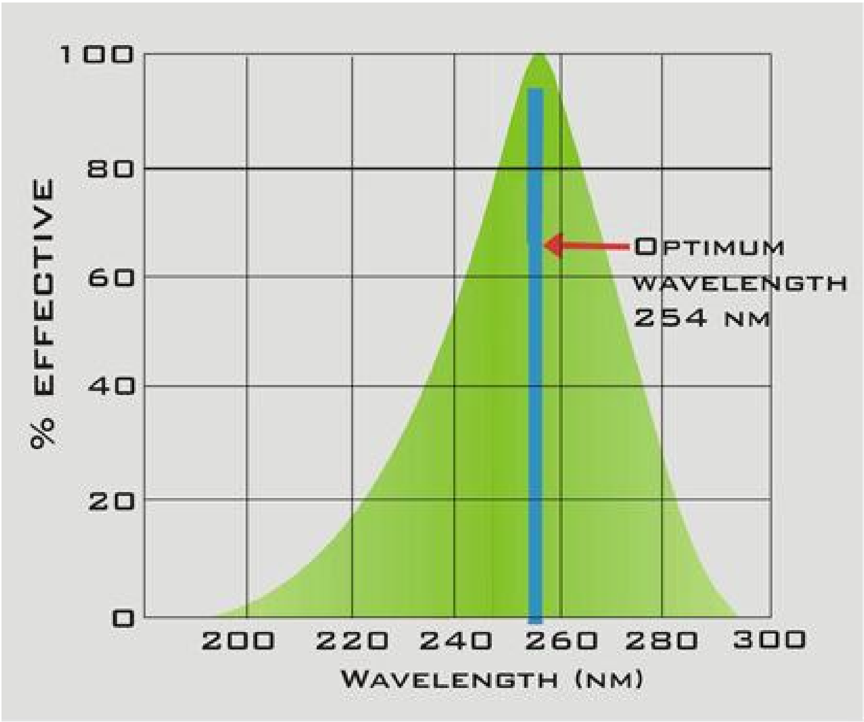

Figure 4: wavelength vs. effectiveness of UV radiation

Source: http://www4.agr.gc.ca/AAFC-AAC/display-afficher.do?id=1241475412160&lang=eng

Through observations, the graph shows that 254 nm is the optimum wavelength and should disinfection the water efficiently.

The disinfection process starts off with low-pressure mercury discharge lamps that emit 254 nm wavelengths. In addition, an electronic arc across the length of the lamp moves through an inert gas containing mercury. The heat generated by the arc vaporizes the mercury; thus gives off UV radiation. The protective transparent housing for bulb is made out of quartz glass, so the UV radiation could travel through it at a much faster rate. As the UV radiation reaches the point where it comes in contact with the water chamber, the disinfection process begins. However, the protective quartz sleeve prevents the water from contacting the UV bulb, so it does not alter or change the temperature of the bulb and the pressure of mercury in the lamp would remain stable. The most common sleeves for the lamp are quartz and Teflon. Using the Teflon sleeve would absorb 35% of the UV radiation, while quartz only absorbs 5%; thus Teflon is generally not recommended for the UV system.[16]

Figure 5: Basic components of UV system
Source: http://www4.agr.gc.ca/AAFC-AAC/display-afficher.do?id=1241475412160&lang=eng

The Ballast Assembly is the control system for the UV lamps power and should be operated at no more than 60°C to prevent any failures. There are two types of ballast: electronic and electromagnetic. However, electronic ballast is most commonly used because it requires less energy, less heat production, longer ballast life, and it allows the ballast to run at high frequency, so the temperature of the lamp would remain cool.

A common misconception people tend to have is that they believe UV radiation can kill microorganisms. However, the purpose of ultraviolet is not to kill these substances, but to alter them. Once the biosand passes the clear infected water through the water chamber, the surviving microorganisms absorbs the UV light and quickly damages their genetic nucleic acid, making them unable to multiplying. Since the organisms cannot replicate, it loses their infection capabilities, so they are not a threat for human or animal consumption.[17]

3.2.3 Economical

The cost can vary from $300 - $900 for installing. Usually an annual replacement of lamp/filter is approximately $150. However, the lamp/bulb itself can cost from $40 - $100 depending on the amount of watts. The UV units operates at low cost and the bulb will loses its disinfection capabilities overtime. Therefore, it is strongly advised to change them once an year, even if it is still operating. From the layout of the new Sub, it is designed to be approximately 31,000 square feet in size and approximately 1,286,474 gallons of rain water could be collected from the SUB roof top in a year. Therefore a great model of ultraviolet system could be the Sanitron in Figure 6.

Figure 6: Sanitron UV water purifier
Source: http:// www.purestfilters.com/ultraviolet.htm

This system is designed for heavy commercial use and can treat 2 to 416 gallons of water per minute [18]; thus it is an ideal design for the new UBC Sub. Since all the components of Ultraviolet systems are separated, maintenance is easy and it does not create a messy environment. Whenever a component needs replacement, it could be easily removed without interfering with the other sections.

4.0 Design

On top of the main components of the filtration system that are responsible for filtering, there are two designs that need to be incorporated into the filtration system – an overflow handling system and a back-flow prevention system. These systems can overcome the challenges of compensating different amount of rainfall throughout the year and can prevent the contaminated water from back flowing into the filtration system.

4.1 OVERFLOW HANDLING DESIGN

An overflow handling system needs to be in place in order to effectively compensate the variation of rainfall we receive in Vancouver. The following table shows the rainfall amount in Vancouver in different months.

Table 7: Vancouver Rainfall Amount Table

Month	Rainfall: mm / inches
January	131.6 / 5.18
February	115.6 / 4.55
March	105.4 / 4.15
April	74.9 / 2.95
May	61.7 / 2.43
June	45.7 / 1.8
July	36.1 / 1.42
August	38.1 / 1.5
September	64.4 / 2.54
October	115.3 / 4.54
November	167.2 / 6.58
December	161.2 / 6.35

Source: http://www.bcpassport.com/vancouver-vital-information/vancouver-climate-tempurature.aspx

The month with the most rainfall can have more than five times rainfall than the month having the least. During the months with high rainfall, irrigation needed for the plant and food will be less and during this period, the cistern runs into the possibility of overflowing. The following section will discuss about the components of an overflowing handling design that can make use of the extra rainwater collected instead of just draining them outside the building.

4.1.1 Components of Overflow Handling System

The main component needed to control the overflow water from the cistern is a sensor that can accurately detect the amount of water in the cistern and can turn valves and pumps on or off in order to redirect the extra rainwater collected. The water level indicator shown below is able to detect depth ranging from 700mm to 4000mm which is a wide range for our cistern.

Figure 7: A Anadex Labs AN4000 Water Level Indicator
Source: http://www.anadexlabs.com/shop/catalog/AQUAMETA-AN4000-Water-Level-Indicator-4m-depth-range-p-2.html

This sensor can be used to detect when the cistern is full and once the cistern is full it can be used to control the valves going into the disinfection stage to shut off and open the valves that allow the water to go into the toilet plumbing system of the SUB. This sensor contain a R232 interface and wireless transmitter that will allow it to implements the type of controls that is required to direct the water into toilet plumbing system. The water that goes into the toilet will be clear because it has gone through the BioSand filter. Since this water is going into the toilet it doesn't need to be disinfected so that resources and time can be saved.

4.1.2 Triple Bottom Analysis of Overflowing Handling Design

The following sections will look into the overflowing handling design from the economical, environmental, and social perspective.

4.1.3 Economical

Being able to use rainwater for toilet plumbing on top of irrigation will allow the new SUB to lower the operation cost by cutting the water rates. Older toilets use around 15 to 30L of water per flush and new toilets must have a maximum flush of 6L. The extra rainwater collected that does not need to be used for irrigation can be used to flush toilets, which can reduce potable water used. The cost to install a control system involves the capital invested in buying valves, and the cistern sensor in which the cost of the cistern sensor is $627.

4.1.4 Environmental

Reduce the use of potable water to flush toilets can result in using less natural resources from the environment. The components used in this control system are not consumable which means there isn't a constant production of waste by using this control system.

4.1.5 Social

The filtered rainwater is designed to go into the toilet plumbing system which acts as an additional source of water. Since the water has been through the Biosand filter, it will be clear and clean just like normal potable water. Therefore, the use of this system will not cause negative impact to its users.

4.2 BACK-FLOW-PREVENTION DESIGN

A back-flow prevention design is needed in any filtration system in order to avoid contaminated water from getting mixed up with filtered water. Since the disinfected water is used for irrigation, implementing back flow prevention valves will reduce the risk of unsanitary water from contacting freshly disinfected water. The pipe that carries the clean water is also connected to other pipes that lead to sources such as toilet plumbing and outside drainage. A back flow can occur when there is a change of pressure in the system. A change in pressure can be caused by damaged equipment which can lead to contaminants flowing back into the filtration system and infect the water. A back-flow prevention valve can be used to prevent water from going into the wrong direction.

Figure 8: 3P Technik Back-flow Prevention Valve
Source: http://www.3ptechnik.co.uk/en/backflowpreventionvalve.html

This device is a one way valve that will only allow the water to flow in one direction. If the water tries to back flow, the valve will close and block the water from entering, so contaminated water will not flow back up the toilet. The cost to maintain and install these valves is low and the valves do not need to be changed regularly. Unfortunately, these valves are not consumable, so they will cause a small impact on the environment.

5.0 CONCLUSION AND RECOMMENDATIONS

As a global leader in campus sustainability, UBC is now aiming for the LEED Platinum+ for the new SUB. One aspect that would contribute to the rating is water efficiency. This report investigates the different filters and disinfection methods for the rainwater collected from the roof of the new SUB. The cistern-collected rainwater will be used to water the rooftop garden that produces food, and because the water will be in direct contact with the fruits and vegetables in the garden, the water will need to be filtered and disinfected before it is used.

The biosand filter is recommended compared to the metal membrane filter primarily because of its lower operating and maintenance cost, and the energy consumption. Using the biosand filter to filter the collected rainwater will eliminate up to 98.5% of bacteria, allowing the water to be stored in the cistern until it is needed. The water sitting in the cistern can be used to flush the toilets in the SUB, but it should still be disinfected before it is used for irrigation due to Food Safe reasons. Chlorination was first considered, but after evaluating its cost and its potential risk to human health, UV is the better choice. Using UV radiation to eliminate the microorganisms in the collected water right before it is used ensures that the highest quality possible water is used to irrigate the rooftop garden. To prevent the filtered water being contaminated by untreated rainwater, backflow handling system and overflow prevention system are recommended to be implemented onto the filtration system. In conclusion, rainwater harvesting is a common practice around the world, but unlike other filtration methods, such as metal membrane or chlorination that others often uses, this report proposes a cost reduction, eco-friendly, and efficient methods, biosand and ultraviolet filtration system, to filter out the contaminated rainwater to nearly 100%; thus proving this as the best solution for the new SUB.

6.0 REFERENCES

[1] R.H. Kim, S *et al.* "Reuse of greywater and rainwater using fiber filter media and metal membrane," in *Desalination*, vol. 202, no. 1-3, Jan. 2007, pp. 326-332.

[2] T. Vandergulik. *Treating irrigation and crop wash water for pathogens*, British Columbia, Jan. 2003. [Online]. Available: www.agf.gov.bc.ca/resmgmt/publist/500Series/512000-3.pdf [Accessed: Mar. 30, 2011].

[3] Centre for Affordable Water and Sanitation Technology, *Biosand Filter Manual*, Centre for Affordable Water and Sanitation Technology, May 2010. [Online]. Available: http://www.cawst.org/en/resources/pubs/file/43-pi-for-bsf-manual-complete-english [Accessed: Mar. 30, 2011].

[4] Centre for Affordable Water and Sanitation Technology, *Summary of Field and Laboratory Testing for the Biosand Filter* , Centre for Affordable Water and Sanitation Technology, Jan. 2008. [Online]. Available: http://www.cawst.org/en/resources/pubs/file/41-field-and-lab-testing-for-bsf [Accessed: Mar. 30, 2011].

[5] SterliTech. "Membrane Disk Filters" Internet: http://www.sterlitech.com/membrane-disc-filters.html, 2011 [Mar. 30, 2011].

[6] Anadex Labs. "Cistern Level Gauges and Control System" Internet: http://www.anadexlabs.com/pdf/AQUAMETA%20AN4000%20Brochure.pdf, September, 2008 [Mar. 30, 2011].

[7] 3P Technik. "3P back-flow prevention valve" Internet: http://www.3ptechnik.co.uk/en/backflowpreventionvalve.html, [Mar. 30, 2011]

[8] Health Canada . "Drinking Water Chlorination". Internet: http://www.hc-sc.gc.ca/hl-vs/iyh-vsv/environ/chlor-eng.php, 2006 [March 31, 2011]

[9] Junsung Kim. (2003, Jan)"Chlorination by-products in surface water treatment process". Desalination,[Online Document] Vol 151, pp1-9. Available http://www.sciencedirect.com.ezproxy.library.ubc.ca/science?_ob=ArticleURL&_udi=B6TFX-47VF5B6-2&_user=1022551&_coverDate=01%2F02%2F2003&_rdoc=1&_fmt=high&_orig=gateway&_origin=gateway&_sort=d&_docanchor=&view=c&_acct=C000050484&_version=1&_urlVersion=0&_userid=1022551&md5=b119b78b73b6c45f63d8eabeb6005624&searchtype=a [March 31, 2011]

[10] Luke Mosley. "Water Quality of Rainwater". Internet: http://www.sopac.int/data/virlib/MR/MR0579.pdf, 2005 [March 31,2011]

[11] Margaret Dyer-Howe. “Disinfection by boiling and chlorination”. Internet: http://www.oas.org/dsd/publications/unit/oea59e/ch23.htm, 1997 [March 31, 2011]

[12] HealthLink BC. “How to Disinfect Drinking Water”. Internet: http://www.healthlinkbc.ca/healthfiles/hfile49b.stm, 2007[March 31, 2011]

[13] J.R. Noll and S.V. Montvila. “Ultraviolet Radiation Purification System” [Online Document], 1988 (Cited 2011 March 15). Available HTTP://www.google.ca/patents?id=1Ow9AAAAEBAJ&zoom=4&dq=ultraviolet%20filtration%20system&pg=PA1#v=onepage&q=ultraviolet%20filtration%20system&f=false

[14] G.H. Sanders. “Filtration and Circulation System For Maintaining Water Quality in Mariculture Tank” [Online Document], 1972 (Cited 2011 March 16). Available HTTP:// www.google.ca/patents?id=-2cuAAAAEBAJ&zoom=4&dq=ultraviolet%20filtration %20system&pg=PA5#v=onepage&q=ultraviolet%20filtration%20 system&f=false

[15] Jian Chen and Minyi Han. “Fluid Ultraviolet Sterilization System” [Online Document], 2009 (Cited 2011 March 15). Available HTTP://patft.uspto.gov/netacgi/nph-Parser?Sect2=PTO1&Sect2=HITOFF&p=1&u=%2Fnetahtml%2FPTO%2Fsearch-bool.html&r=1&f=G&l=50&d=PALL&RefSrch=yes&Query=PN%2F7482599

[16] Agriculture and Agri-Food Canada. “Water Treatment: Ultraviolet Disinfection of Private Water Supplies for Household or Agricultural Uses” [Online Document], 2009 (Cited 2011 March 20). Available HTTP://www4.agr.gc.ca/AAFC-AAC/display-afficher.do? id=1241475412160&lang=eng

[17] L.K. Wang and L.K. Latham. “Contamination Removal System Employing Filtration and Plural Ultraviolet and Chemical Treatment Steps and Treatment Mode Controller” [Online Document], 1993 (Cited 2011 March 20). Available HTTP:// www.google.ca/ patents?id=rAAgAAAAEBAJ&zoom=4&dq=ultraviolet%20filtration%20system&pg=PA18#v=onepage&q=ultraviolet&f=false

[18] Purest Filters. “Ultraviolet Water Purification Products”. [Online Document], 2010 (Cited 2011 March 30). Available HTTP://www.purestfilters.com/ultraviolet.htm