# Water Quality of Jurong Eco-Garden Pond System Cleansing Biotope Cells

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## Abstract

Singapore faces several geographical limitations, one of which is the small land area. With the rapid urbanisation in this small city, Singapore faces the issue of transport pollution and that of limited natural freshwater resources. Additionally, Singapore receives abundant precipitation especially during the monsoon seasons, namely during the wet phase of the Northeast monsoon (between the months of December and January) and during the Southwest monsoon season (between the months of June and September). In order to fully utilize the storm-water collected, cleansing biotopes in Singapore are first implemented in 2012 at the Bishan-Ang Mo Kio Park jointly by Public Utilities Board (PUB) and National Parks Board (NParks) for the natural treatment of water. The cleansing biotope is a natural water treatment concept that utilises carefully selected plants for absorption of excess nutrients in water and differentiated soil layers as a filter medium. They offer effective water treatment while maintaining a natural and beautiful environment.

Our research project aims to examine the characteristics and properties of a cleansing biotope, and to understand its working principle in maintaining water quality at our local parks – such as the Jurong Eco-Garden, where a cleansing biotope is already in place and is being studied for its water quality maintenance and conservation properties. Our project will focus on testing the water quality in the Jurong Eco-Garden pond system and evaluating the performance of the cleansing biotopes in treat the water. Our long term vision is that effective application of cleansing biotopes can contribute to the overall quality of water collected and lead to a reduction in energy and manpower resources used for conventional water treatment procedures.

## Keywords

Cleansing Biotopes, Water Quality, Jurong Eco-Garden, Singapore

# 1 Introduction

Singapore is a tropical island situated 1.5° north of the Equator which experiences a warm and wet climate. Its annual precipitation averages at 2400 millimetres, usually occurring as storms in the form of storms which include monsoon surges, Sumatra Squalls and sea breeze-induced thunderstorms (PUB *et al*, 2013). The wettest month yearly in Singapore is usually December.

Since Singapore is land scarce and prone to facing high intensity rainfalls, it is necessary to consider effective stormwater runoff management techniques, to manage the problem of flooding. This is especially so with the increase in impermeable surfaces over the years of Singapore's rapid urban development. Furthermore, given our island state's limited physical space serving as rainfall catchment area, there is great value in considering how best to maximise the usage of this stormwater before it drains into the sea. In such a context, our team believes that the implementation of cleansing biotopes is an invaluable stormwater management strategy. Not only does it address the problem of flooding, filtered stormwater from cleansing biotopes have been found to reduce the dependency on potable water for activities which do not require uncontaminated water such as irrigation, washing and flushing toilet systems). We hope to research ideas and ways to expand the potential of cleansing biotopes to further improve water quality.

To achieve our objective, our project is split into 3 main stages. Stage 1 comprises literature review and secondary research on cleansing biotopes which will then inform our planning and design of Stage 2, when we undertake fieldwork and data collection at our test site, Jurong Eco-Garden. Stage 3 would be the application of our findings from the field in proposing some key characteristics of a highly efficient cleansing biotope which we hope to represent in the form of a 3D model render using Google SketchUp Software.

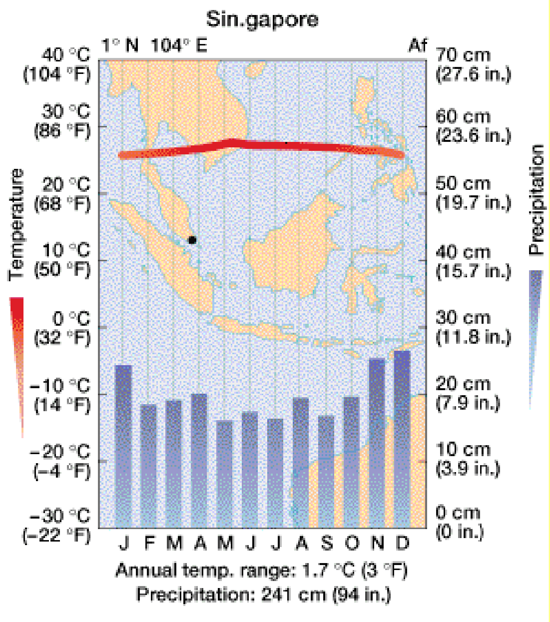



Figure 1: Climograph of Singapore (M.P, 2012)

## 1.1 Cleansing Biotopes

### 1.1.1 What are Cleansing Biotopes?

A cleansing biotope is a natural water treatment strategy that utilises plantings of carefully selected wetland plants which help to cleanse the water by absorbing the nutrients. At the same time, the different soil layers act as the filter medium that removes pollutants and particulates from the water (PUB, 2011). The water filters through the plant root systems, where contaminants are removed and treated by bacterial activity on the root surface (PUB, 2011). The treated water from the cleansing biotope's cells is then channelled into the large pond and used for other amenities (PUB, 2011). Figure 2 shows the essential components of a cleansing biotope.

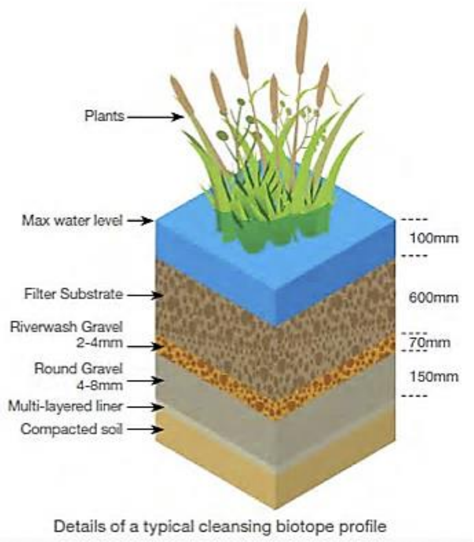



Figure 2: Profile of Cleansing Biotope Design by PUB (2014)

### 1.1.2 Benefits of Cleansing Biotopes (ABC Waters Design Guidelines, 2011)

Cleansing Biotopes play an aesthetic and practical ecological role when planted in the environment:

- Biotopes are able to slow down stormwater runoff and improve the water quality naturally without the use of any chemicals.
- Cleaned stormwater stored on-site can be reused and recycled purposefully for a wide range of non-potable uses such as irrigation, general washing. Hence, biotopes are involved in the reduction of potable water consumption.
- Biotopes, as part of constructed wetlands, present themselves as multi-functional spaces which serve as recreational and educational platforms for the general public to interact and discover about green spaces and eco-efficient water treatment.
- Biotopes are suitable for implementation in ecologically-sensitive areas, public parks, urban open spaces and rural areas.
- They are cost-effective, sustainable and environment-friendly features for urban stormwater management. The cost is a small percentage of the total capital cost of the development, while the resulting environmental benefits are many.

### 1.1.3 Why were biotopes introduced and constructed in Singapore?

As a global first-class, city state, water autonomy is definitely of top concern for Singapore. Singapore's tropical climate provides plenty of water. However this falls in fierce downpours which create a challenging situation in terms of flood management and water quality, our island state having limited land available for expanding drainage systems in the face of rapid urbanisation, population and economic growth. Although the state has had the foresight to ensure reliable sources of water for the nation in the form of the '4 National Taps' (PUB, 2016), the ever-growing demand for water (both potable and non-potable sources) is a relevant worry.

Since our city is also densely inhabited, the quality of urban space directly affects citizens' quality of life. Our city's drainage system is largely concretised and canalised, due to hard engineering solutions implemented in the past. Large, standalone, and concrete canals, such as the Alexandra Canal (PUB, 2013), are typical in Singapore. This massive concrete engineering method is very efficient but not aesthetically appealing. Furthermore, runoff collected in them flow into water catchments without any form of filtering. Given that two-thirds of Singapore's land is water catchment area (PUB, 2015), it is critical that we leverage every opportunity to capture and clean stormwater runoff before it is channelled into the reservoirs.

Thus, in order to meet the increasing water needs in a sustainable manner and uphold the liveability of an urbanising country, Singapore's national water agency, Public Utilities Board (PUB), initiated the ABC Waters Management Strategy to enhance the value of Singapore's public waterways. PUB's strategic initiative to improve the quality of water and life by harnessing the full potential of Singapore's water bodies is seen through its many implementations. Hence, this idea of cleansing biotopes was brought up as an efficient and aesthetically-pleasing strategy to meet the ever-growing demand for water, both non-potable and potable. Cleansing biotopes were included as part of an integrated design targeted at 'improving runoff water quality from the development site into the receiving environment' and 'maximising the aesthetics and recreational amenities of developments' (PUB, 2010). Cleansing biotopes which were previously implemented in parts of Singapore, are said to have increased the aesthetic appeal of that particular site, an example of which would be the newly renovated Bishan-Ang Mo Kio Park site, as shown in figure 3 below.

These improvements are largely approved and supported by members of the general public, evident through their frequent visits to these sites. Therefore, cleansing biotopes are largely warmly welcomed as a strategic idea to improve water quality in highly-populated and massively urbanised area, where space is a precious resource.

## 1.2 Purpose of Investigation

Our research project aims to examine if the current configurations of cleansing biotope are effective in treating water and to understand its working principle in maintaining water quality at our local parks – such as the Jurong Eco-Garden, where a cleansing biotope is already in place and is being studied for its water quality maintenance and conservation properties.

Our project will focus on finding the key factors behind effective cleansing biotope design that can improve the quality of surface runoff before they are emptied into the lakes and reservoirs.

In the long run, we hope that by effective application of refined cleansing biotopes, they can contribute substantially to the overall quality of water collected. And therefore lead to a momentous reduction in valuable energy and

Figure 3: Cleansing Biotope Cells in Bishan Ang Mo Kio Park, Singapore (2013)

manpower resources typically used for conventional water treatment procedures.

## 1.3 Hypothesis

Given a detailed explanation of the function of the cleansing biotopes, we hypothesised that the water will have a significant improvement in quality upon leaving the biotope. Indicators of water quality improvement include: a reduction in E.coli count, in turbidity level, phosphate, nitrate levels and in total dissolved solids.

# 2 Sample Areas and Data Collection Methods

## 2.1 Fieldwork sites at Jurong Eco-Garden

Figure 4: Location of the 5 fieldwork sites on the map of Jurong Eco-Garden

## 2.2 Justification of Choice of Fieldwork Site

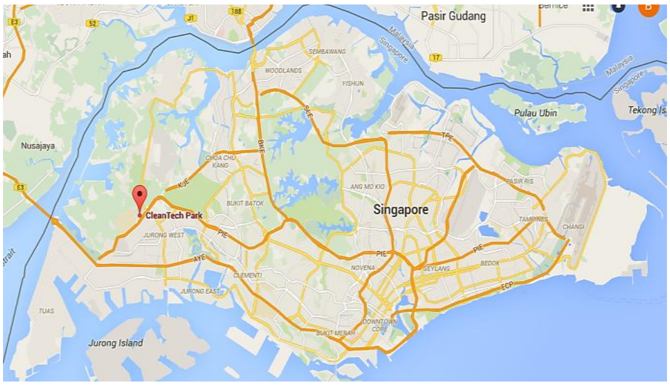



Figure 5: Location of Jurong Eco-Garden (situated at CleanTech Park) in the Singapore (Google Maps, 2015)

Jurong Eco-Garden (JEG) is located at the western region of Singapore, as part of CleanTech Park, an eco-business park opened by the Jurong Town Corporation (a statutory board of Singapore's Ministry of Trade and Industry) as an urban "green space", with the purpose of recreation, both for residents in the nearby housing estates and for employees working in CleanTech Park, and ecological preservation in mind.

As the JEG is sited adjacent to dense residential areas and industrial buildings, concentrations of heavy metal ions and pollutants in the surface runoff would be expected to be greater. The Eco-Garden was built with adherence to the "ABC (Active, Beautiful, Clean) Waters" design guidelines and features, with abundant landscaping and garden feature such as a butterfly garden and a forest trail. Most important would be its flagship feature, a three celled cleansing biotope strategically located to receive runoff from the more elevated north and northeast, and planted with riparian plants to clean the water through sedimentation, filtration and nutrient uptake, and offering a variety of biotope designs.

We believe that the chosen catchment area is an appropriate case study for plant-based water cleansing solutions in the urban ecosphere. Not only does it provide an excellent in-depth understanding of the way water quality is adversely affected by proximal industrial processes located at a government-designated industrial town, it also indicates how cleansing biotopes may compensate for increased surface runoff and decreased water quality with different strategies and materials.

## 2.3 Description of 5 Fieldwork Sites in Jurong Eco-Garden

### 2.3.1 Site 1

Figure 6: Site 1

Site 1 is a pond situated before the cleansing biotopes. It is also the 'Upstream' site where one of the YSI Datasonde is situated.

### 2.3.2 Site 2

Site 2 is the first cell of the cleansing biotope feature, as detailed in figure 7 below, and measurements are of water draining into the cleansing biotope from the collection pond in Site 1.

Figure 7: Site 2

### 2.3.3 Site 3

Site 3 is situated at the end of all the cleansing biotope cells, whereby water which has passed through them would flow out into the underground cistern. Readings here would supposedly capture the effect of the cleansing biotope on water parameters.

Figure 8: Bridge Near Site 3

Figure 9: Site 3 from the perspective from the bridge

### 2.3.4 Site 4

Figure 10: Site 4

Site 4 is located at an upstream swale near a carpark. Traces of oil are often found at the water sampling site.

### 2.3.5 Site 5

Figure 11: Site 5

Site 5 is an upstream site of a cleansing biotope cell. For most weeks, this cell is not filled with much vegetation.

## 2.4 Sampling Dates and Corresponding Weather Conditions

Table 1 Sampling Dates and Corresponding Weather Conditions

| Fieldwork Week | Date & Time | Weather Conditions | | | |
|---|---|---|---|---|---|
| | | **Temperature** | **Wind Speed** | **Relative Humidity** | **Weather** |
| Week 1 | Thursday, 7th Jan 2016, 4.14pm | 32°C | 1.8 m/s | 55% | Cloudy |
| Week 2 | Thursday, 14th Jan 2016, 3.40pm | 31.1°C | 1.1 m/s | 64.4% | Sunny (After slight drizzle) |
| Week 3 | Sunday, 17th Jan 2016, 2.00pm | The team was unable to track weather conditions due to heavy storm. | | | Heavy storm (From 1.50pm to 2.48pm - 58 mins) |
| Week 3 (STORM) | Monday, 18th Jan 2016, 8.00am | 32.7°C | 0.6m/s | 65.1% | Sunny |
| Week 4 | Monday, 25th Jan 2016, 4.50pm | 30.5°C | 1.5 m/s | 61.5% | Cloudy |
| Week 5 | Monday, 1st Feb 2016, 4.30pm | 31.1°C | 0.9m/s | 56.9% | Cloudy (Presence of dark clouds) |
| Week 6 | Tuesday, 9th Feb 2016, 8am | 27.3°C | 0.5m/s | 68.6% | Cloudy |
| Week 7 | Thursday, 18th Feb 2016, 5.35pm | 28.8°C | 0.7m/s | 73.9% | Cloudy (Drizzled before fieldwork) |
| Week 8 | Thursday, 25th Feb 2016, 4.00pm | 30.5°C | 1.2m/s | 59.0% | Sunny |
| Week 9 | Monday, 7th Mar 2016, 5.00pm | 29.7°C | 0.7m/s | 66% | Cloudy |

## 2.5 Data Collection

Water samples from each site were collected using a scooper and put into labelled bottles. The bottles of samples were thereafter be brought to the laboratory for water quality testing, which will be elaborated upon under *4 Materials and Methods*.

Figure 12: Jing Yuan (left) and Priscilla (right) collecting a bottle of water sample from Site 5.

Additionally, in order for data to be downloaded from the YSI Datasonde, two members had to unlock them from the ladder under the manhole (Figure 13) and rinse them before connecting it to a laptop (Figure 14).

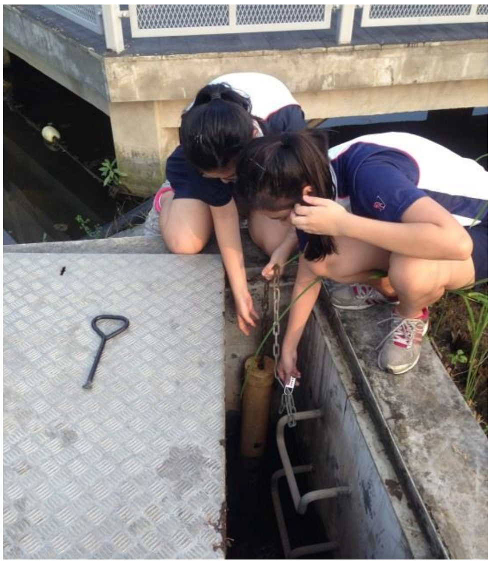


Figure 13: JingYuan (left) and Priscilla (right) unlocking a YSI Datasonde from the Site 3 manhole.

Figure 14: Priscilla (left) and Jing Yuan (right) preparing the YSI Datasonde for the downloading of data. Cylinder beside Jing Yuan is a protective casing for the YSI Datasonde when it is submerged in the pond.

Figure 15: Priscilla (left) and Jing Yuan (right) using a laptop to download data from a connected YSI Datasonde.

## 2.6 Justification of Factors Investigated

Table 2 Justification of Factors Investigated

| **Factor** | **Justification** |
|---|---|
| Nutrients | The higher the amount of nutrients in the water, the more prone it will be to the growth of algae, planktons and eutrophication to occur. Eutrophication is a condition in an aquatic ecosystem where high nutrient concentrations stimulate blooms of algae (e.g., phytoplankton) *(Eutrophication and Algae Bloom, n.d.)*. |

| | |
|---|---|
| Dissolved Oxygen (DO) Levels | Dissolved oxygen is one of the most important parts of water quality. Oxygen, although poorly soluble in water, is fundamental to aquatic life. Without free dissolved oxygen, streams and lakes become uninhabitable to aerobic organisms (a microorganism that lives and grows in the presence of free oxygen), including fish and most invertebrates *(WATER CHEMISTRY – Data Interpretation and Standards, n.d.)*. Dissolved oxygen is inversely proportional to temperature. The saturation value decreases rapidly with increasing water temperature. Saturation value also decreases with increasing water salinity. Hence, given that Jurong Eco-Garden is a constructed freshwater swamp, it is expected that the water samples have higher DO sat %. |
| Turbidity | Turbidity is caused by many materials, such as clay deposits, tiny inorganic materials, algae and other inorganic matter. Turbidity is of great importance, because it affects the aesthetic levels of the site, and also because the presence of tiny colloidal particles makes it more difficult to remove or inactivate pathogenic (**Pathogenic** is a medical term that describes viruses, bacteria, and other types of germs that can cause some kind of disease.) organisms.<br><br>Algae: Slow growing autotrophic micro-organisms which use nutrients present in water, carbon dioxide, water and sunlight to grow. They are a huge problem, mainly because they are often difficult to remove from raw water and a potential concern, because some species of algae produce toxins |
| E.coli | Escherichia coli, commonly referred to as E. coli, is a member of a group of organisms known as coliforms: common bacteria found in the digestive system of humans and animals *(Lewei, n.d.)*. This organism is usually not a cause for concern, as there are only a few strains that cause serious disease in humans *(Lewei, n.d.)*.<br><br>E.coli count varies with the weather and seasonal patterns, bacteria numbers often increase after a heavy storm or due to excessive runoff from the surrounding grass beds. E. coli bacteria are often more prevalent in turbid waters because they live in soil and can easily attach to sediment particles. Bacteria can also remain in streambed sediments for long periods of time *(Bacteria and Water Quality, n.d.)*. If the streambed has been stirred up by increased flow or rainfall, the sample could have elevated bacteria levels. Human-activities may also cause the stirring up of sediments from the streambed. Also, increased E. coli counts may be found in warmer waters because they survive more easily in these waters *(Bacteria and Water Quality, n.d.)*. Ultraviolet rays from the sun, however, can also kill bacteria. Singapore's daily weather is prevalently warm and sunny, so it may produce numbers lower than expected.<br><br>Impacts of E.coli: Diseases acquired from contact with contaminated water can cause gastrointestinal illness, skin, ear, respiratory, eye, neurologic, and wound infections. The most commonly reported symptoms are stomach cramps, diarrhoea, nausea, vomiting, and low-grade fever. Lower thresholds have been set for the drinking water standards, if exceeded, users may need to boil the water before consumption *(Lewei, n.d.)*.<br><br>When E. coli exceeds the permissible level in recreational water, it results in the closing of beaches, ponds, lakes, and swimming and fishing areas *(Lewei, n.d.)*. |
| pH Levels | The reason for testing for pH value is because even minor pH changes can have long-term effects. A slight change in the pH of water can increase the solubility of phosphorus and other nutrients – making them more accessible for plant growth. In a lake low in plant nutrients and high in dissolved oxygen levels, this can cause a chain reaction. With more accessible nutrients, aquatic plants and algae thrive, increasing the demand for dissolved oxygen. This creates a eutrophic lake, rich in nutrients and plant life but low in dissolved oxygen concentrations. In a eutrophic lake, other organisms living in the water will become stressed, even if pH levels remained within the optimum range.<br><br>pH levels are responsible for the proper chemical treatments given, in disinfection and corrosion control as well as the suitable water treatment. As such, monitoring the pH level is of utmost importance.<br><br>Low pH levels can encourage the solubility of heavy metals. As the level of hydrogen ions increases, metal cations such as aluminum, lead, copper and cadmium are released into the water instead of being absorbed into the sediment. As the concentrations of heavy metals increase, their toxicity also increases. |

| | |
|---|---|
| | On the other hand, high pH levels can damage gills and skin of aquatic organisms and cause death at levels over 10.0. Aquatic organisms are sensitive to pH changes, few of them can tolerate waters with a pH less than 4 or greater than 10. The biotope at the JEG cells does contain aquatic life, so monitoring the pH level to ensure sustainability of the aquatic life is paramount to prevent detrimental effects to the aquatic organisms. |
| Total Dissolved Solids | Total dissolved solids are the total amount of mobile charged ions, including minerals, salts and metals dissolved in a given amount of water *(What is TDS?, n.d.)*. It is used as an indicator test to determine general water quality *(Oram, n.d.)*. |
| Specific Conductance | SpCond reflects how well the water can conduct electricity and shows the content of ionic substances in water (Dane, Adam, Davis, Keseley, 2005). Since most solids dissolved in river waters are ionic, the SpCond is a measure of the amount of dissolved solids in water (Dane el at., 2005). When SpCond increases, it means the water is receiving more dissolved solids from storm run-off or underlying aquifers. Since rainwater contains no dissolved solids, SpCond usually decrease after precipitation events with extent to drop related to amount of precipitation. |

## 2.7 Sampling Methods

### 2.7.1 Physical testing

Physical tests on dissolved oxygen, phosphate and nitrate were completed using Colorimetric Approach (CHEMetric Inc.). Physical tests on e.coli and turbidity were also completed using coliscan easygel and, turbidity tube as well as Lovibond Turbidity Meter respectively.

### 2.7.2 Continuous Logging

YSI 6920 V2 Datasondes were installed at Site 1 (upstream site) and Site 3 (downstream site). The datasondes recorded temperature, dissolved oxygen, conductivity, turbidity and pH at 15 minute time steps for the periods of 12/28/15 - 3/7/16. The locations of these fixed sample sites were based on the flow of water before it enters the cleansing biotope and after it passes the biotopes. This will provide a good trend on the effectiveness and characteristics of the cleansing biotopes.

General

- Droppers
- Funnel
- Kestrel 4000 Pocket Weather Meter
- Labels
- Oxygen Probe Service Kit

Water Quality Testing

- Coliscan Easygel
- Dissolved Oxygen CHEMets Kits
- Nitrogen CHEMets Kits
- Petri dishes
- Phosphate CHEMets Kits
- Turbidity tube

Water Sampling

- Bottles for storage of water samples
- Funnel
- Permanent marker
- Masking tape
- Scooper

YSI 6920 V2 Multi-Parameter Water Quality Sonde

- AA and A batteries
- Cotton buds
- Locks & Keys
- pH buffer 7
- pH buffer 10
- Screwdriver
- Sensors: Temperature, Conductivity, Dissolved Oxygen, pH and Turbidity

## 2.8 Fieldwork Procedures

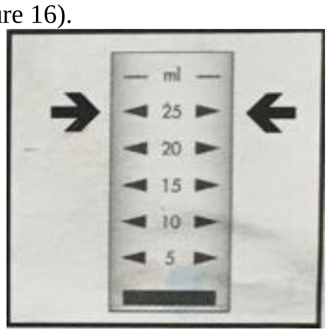
**1. Dissolved Oxygen CHEMets Kit** (CHEMetric, Inc.)

**Sampling**

The most critical part of any dissolved oxygen test is sampling. It is difficult to obtain an aliquot that accurately reflects the oxygen content of a sample. Exposure to the high content of "air" will cause a sample to approach saturation. Biological activity may cause rapid oxygen depletion. Dipping and pouring operations should be performed with as little agitation as possible.

**Test Procedure**

1. Fill the sample cup to the 25 mL mark with the sample to be tested (Figure 16).




2. Place the ampoule in the sample cup. Snap the tip by pressing the ampoule against the side of the cup. The ampoule will fill, leaving a small bubble to facilitate mixing (Figure 17).

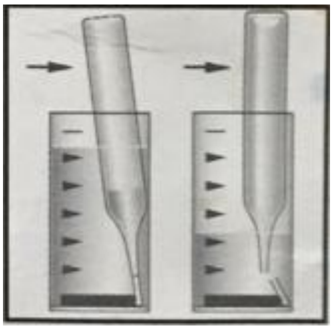


**Figure 17**

3. Mix the contents of the ampoule by inverting it several times, allowing the bubble to travel from end to end. Dry the ampoule and wait 2 minutes for colour development.

4. Hold the comparator in a nearly horizontal position while standing directly beneath a source of light. Place the ampoule between the colour standards, moving it left to right along the comparator until the best colour match is found. (Figure 18) If the colour of the ampoule is between two colour standards, a concentration estimate can be made.

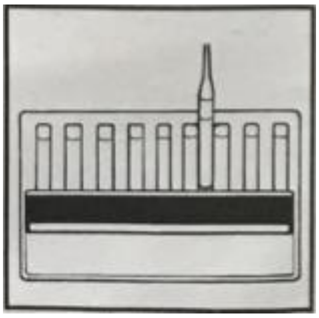


**Figure 18**

**2. Nitrate CHEMets Kit** (CHEMetric, Inc.)

**<u>Test procedure</u>**

1. Fill the reaction tube to the 15 mL mark with the sample to be tested. Empty the contents of one Cadmium Foil Pack into the reaction tube (Figure 19).

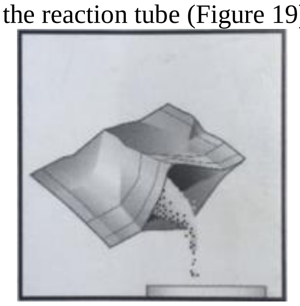


**Figure 19**

2. Cap and shake vigorously for exactly 3 minutes. Allow the sample to sit undid turned for 2 minutes.

3. Pour 10 mL of the treated sample into the sample cup (Figure 20), being careful not to transfer any cadmium particles to the sample cup.

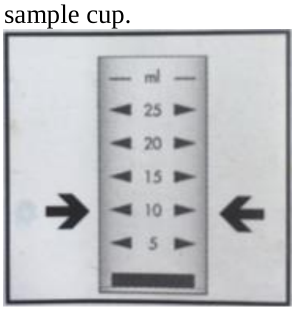



**Figure 20**

4. Place the CHEMet ampoule into the sample cup. Snap the tip by pressing the ampoule against the side of the cup. (Figure 21) The ampoule will leave a small bubble to travel from end to end. Dry the ampoule and wait 10 minutes for colour development.

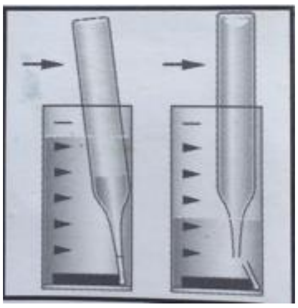


**Figure 21**

5. Mix the contents of the ampoule by inverting it several times, allowing the bubble to travel from end to end. Dry the ampoule and wait 10 minutes for colour development.

6. Hold the comparator in a nearly horizontal position while standing directly beneath a source of light. Place the ampoule between the colour standards moving it from left to right along the comparator until the best colour match is found. If the colour of the ampoule is between colour standards, an estimate can be made. (Figure 22).

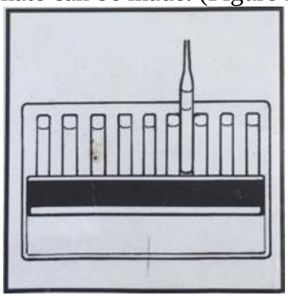


**Figure 22**

**3. Phosphate CHEMets Kit** (CHEMetric, Inc.)

**<u>Test Procedure</u>**

1. Fill the sample cup to the 25 mL mark with the sample to be tested (Figure 23).

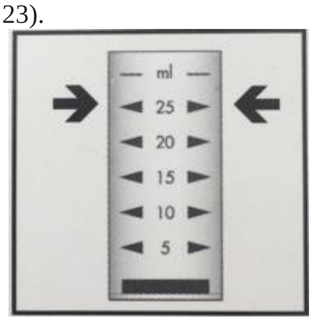



**Figure 23**

2. Add 2 drops of A-8500 Activator Solution (Figure 24). Cap the sample cup and shake it to mix the contents well.

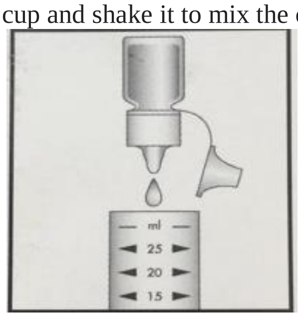



**Figure 24**

3. Place the CHEMet ampoule, tip first, into the sample cup. Snap the tip carefully. The ampoule will fill, leaving a bubble for mixing (Figure 25).

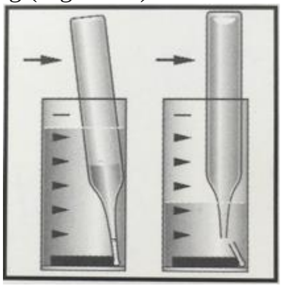


**Figure 25**

4. To mix the ampoule, invert it several times, allowing the bubble to travel from end to end.
5. Dry the ampoule and wait for 2 minutes for colour development.
6. Obtain a test result using the appropriate comparator. à Low Range Comparator: (Figure 26) Place the ampoule, flat end first, into the comparator. Hold the comparator up toward a source of light and view from the bottom. Rotate the comparator until the best colour match is found.

**Figure 26**

**4. YSI 6920 V2 Datasondes**
**Methodology**

1. Connect the YSI to a laptop and open the 'Eco Lite' software.
2. Calibrate the Dissolved Oxygen sensor. (Select: Option 2 (DOsat%) of the next page and proceed by pressing in the surrounding pressure measurements in mmHg units)
3. Begin the logging of data.
4. Disconnect the YSI from the laptop and secure it to the ladder under the manhole for a week.
5. After a week, remove the YSI from the manhole and rinse it clean with water.
6. Connect it to the laptop and 'Eco Lite' Software.
7. Download the data into the software.
8. Repeat from Step (2) to continue another round of data collection.

**5. Coliscan Easygel**
**Methodology**

1. Agitate the bottle to avoid sedimentation and ensure even spread of nutrients.
2. With the use of droppers, transfer 5ml of water sample to the bottle of E.coli easy gel.
3. Swirl the mixture. Do not shake to avoid formation of air bubbles.
4. Pour the mixture evenly on the petri dish.
5. Label the petri dish.

**6. Turbidity**
**Turbidimeter (YSI)**

Turbidity is measured using a turbidimeter, they are photometers that measure the intensity of scattered light (Vesilind, P. A., Peirce, J. J., & Weiner, R. F. (1994). *Environmental engineering*. Boston: Butterworth-Heinemann). Opaque particles scatter light, so scattered light measured at right angles to a beam of incident light is proportional to the turbidity (Vesilind el at., 1994). *Formazin polymer* is used as the primary standard for calibrating turbidimeters and the results are reported as *nephelometric turbidity units (NTU)* (Vesilind el at., 1994).

**Turbidity Tube**
**Methodology (Myre, Shaw, 2006)**

1. Rinse the tube with water that is going to be tested.
2. Position head 10 to 20 centimeters directly over the turb so that the viewing disk is visible while the water sample is being poured into the tube.
3. Pour water sample slowly into the tube. Try not to form bubbles as water is being poured. If bubbles form: Stop pouring and allow bubbles to rise and the surface of the water to become still.
4. Keep adding the water sample until the pattern on the disc becomes hard to see.
5. Watch the viewing disk closely as water is added even slowly.
6. Stop pouring once pattern on the disk can no longer be seen.
7. Read and record the turbidity from the scale on the side of the tube.

# 3 Results and Analysis

## 3.1 Physical Data Obtained From 5 Sites

### 3.1.1 Comparing Nutrient Levels

Referring to Tables 3 and 4, from Week 1 to Week 9, all 5 sites showed consistent phosphate levels of 0 – 1 PPM.

Similarly, almost all the data collected at all the 5 sites showed a consistent nitrate levels of 0 PPM. Despite having a small number of sites showing 0.4 PPM and 0.6 PPM nitrate levels during certain weeks, these anomalies are random and showed very little difference in nitrate levels. No clear trend at these sites for these anomalies could be established.

### 3.1.2 Comparing Dissolved Oxygen (DO) Levels

For each of the weeks from Week 1 to 4, all sites showed similar high DO levels, ranging from 6-10 and for each week, the sites only have a slight difference of 1 – 2.

Table 3. Phosphate levels at the 5 sites from Week 1 – 9

<table>
<tr><th></th><th>Week / Site</th><th>1</th><th>2</th><th>3 (STORM)</th><th>3</th><th>4</th><th>5</th><th>6</th><th>7</th><th>8</th><th>9</th></tr>
<tr><td rowspan="5">Phosphate levels / PPM (mg /L)</td><td>1</td><td rowspan="5">0-1</td><td rowspan="5">0-1</td><td rowspan="5">0-1 (Site 1, 3, 4)</td><td rowspan="5">0-1</td><td rowspan="5">0-1</td><td rowspan="5">0-1</td><td rowspan="5">0-1</td><td rowspan="5">0-1</td><td rowspan="5">0-1</td><td rowspan="5">0-1</td></tr>
<tr><td>2</td></tr>
<tr><td>3</td></tr>
<tr><td>4</td></tr>
<tr><td>5</td></tr>
</table>

Table 4. Nitrate levels at the 5 sites from Week 1 to 9

<table>
<tr><th></th><th>Week / Site</th><th>1</th><th>2</th><th>3 (STORM)</th><th>3</th><th>4</th><th>5</th><th>6</th><th>7</th><th>8</th><th>9</th></tr>
<tr><td rowspan="5">Nitrate levels / PPM (mg /L)</td><td>1</td><td rowspan="5">0</td><td rowspan="5">0</td><td rowspan="5">0 (Site 1, 3, 4)</td><td rowspan="5">0</td><td rowspan="5">0</td><td>0.4</td><td rowspan="5">0</td><td>0</td><td rowspan="5">0</td><td rowspan="3">0</td></tr>
<tr><td>2</td><td rowspan="4">0</td><td>0.6</td></tr>
<tr><td>3</td><td rowspan="3">0</td></tr>
<tr><td>4</td><td>0.4</td></tr>
<tr><td>5</td><td>0</td></tr>
</table>

Table 5. Dissolved Oxygen Levels at the 5 sites from Week 1 to 4

<table>
<tr><th></th><th>Week / Site</th><th>1</th><th>2</th><th>3 (STORM)</th><th>3</th><th>4</th></tr>
<tr><td rowspan="5">Dissolved Oxygen Levels / PPM (mg /L)</td><td>1</td><td rowspan="5">8</td><td rowspan="5">8</td><td rowspan="5">8 (Site 1, 3, 4)</td><td>8</td><td>6</td></tr>
<tr><td>2</td><td>10</td><td>6</td></tr>
<tr><td>3</td><td>8</td><td>6</td></tr>
<tr><td>4</td><td>8</td><td>6</td></tr>
<tr><td>5</td><td>8</td><td>7</td></tr>
</table>

## 3.1.3 Comparing Turbidity Levels

With reference to Figure 27, the waters at Site 3 and Site 4 were generally more turbid as compared to the 3 other sites, as shown by the differing heights of the bar graphs.

By contrast, Sites 1, 2 and 5 are generally less turbid, with close to similar turbidity levels throughout the 9 weeks.

There is a slight decrease in turbidity in sites during week 4. There was also a slight increase in turbidity for all sites in week 5.

Site 4 was surprisingly clear despite being an upstream site. It had exceeded the turbidity tube's measurement of 120 cm maximum, 5 times in the span of 9 weeks.

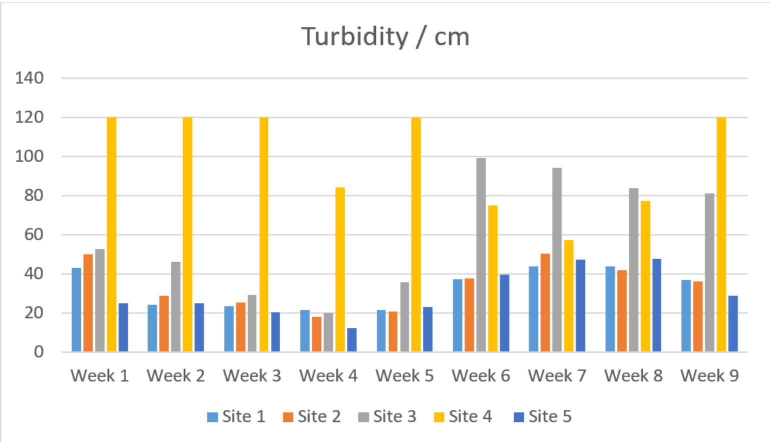



Figure 27. Bar graph showing the turbidity levels at the 5 sites from Week 1 to 9

*(The above turbidity data collected and presented in 5.1.3 was obtained using a turbidity tube with a maximum reading of 120cm.)*

### 3.1.4 Comparing E.coli Count

From Figure 28, relative to Site 1 and Site 4 which has generally very low E.coli count, Site 2 and Site 3 generally have very high E.coli count, while no clear trend could be determined for Site 5 as it has frequent fluctuations in E.coli count. Overall, the E.coli count is low.

In addition, it could be observed that during Week 3 Storm and Week 4's data collection, it showed the highest E.coli readings at all 5 sites.

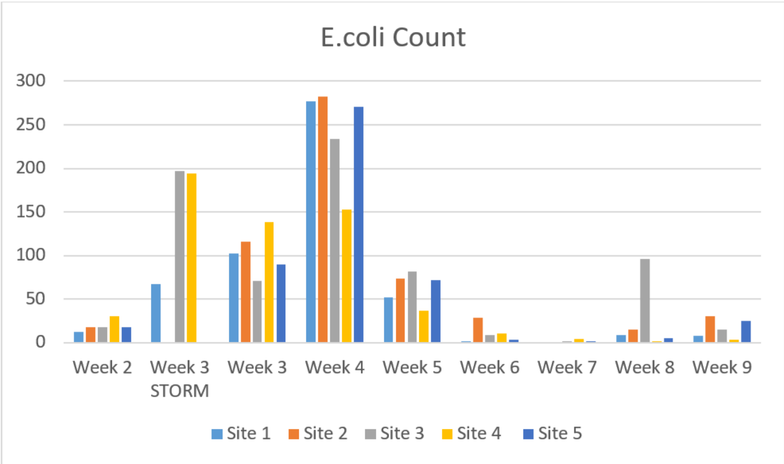



Figure 28. Bar graph showing the E.coli count / number of e.coli colonies at the 5 sites from Week 2 to 9 (all carried out using Easygel Coliscan)

### 3.1.5 Comparing Total Dissolved Solids

Based on our hypothesis, we expected the total dissolved solids in Sites 1, 2, 4 and 5 to be higher than that in Site 3. This hypothesis is generally true with the exception of Site 4 having lower total dissolved solids as compared to the Site 3.

Generally, Site 4 has the lowest amount of total dissolved solids amongst all sites, with the exception of Week 4 and 5.

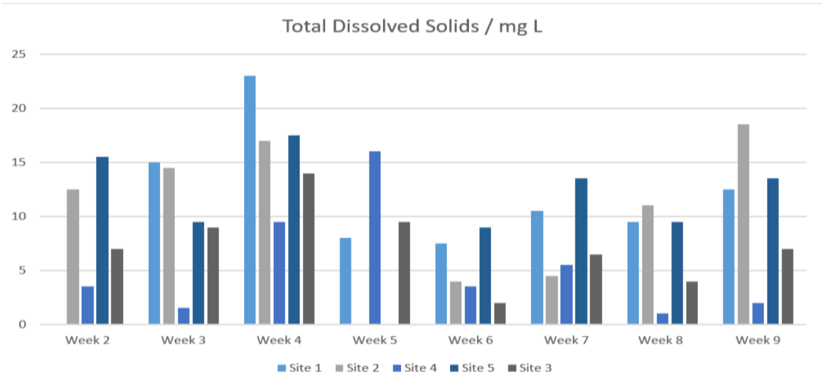



Figure 29. Bar graph showing the Total Dissolved Solids at 5 sites from Week 2 to Week 9

## 3.2 YSI Data At Upstream Site (*Site 1)* and Downstream Site (*Site 3)*

### 3.2.1 Comparing Dissolved Oxygen Levels

From the data obtained from the YSI, the upstream site has an evidently much higher DO sat % [*range 70 - 140%*] and DO mg/L [*range 5.75 - 10.25 mg/L*]. The downstream site has a much lower DO sat % [*range 10 - 35%*] and DO mg/L [*range 0.75 - 2.75 mg/L*].

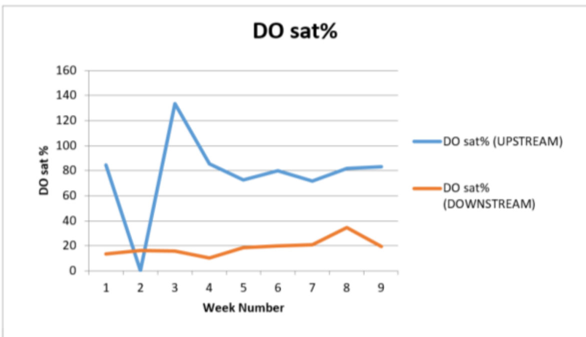



Figure 30. Line graph showing mean DO sat % at upstream site and downstream site
*(*Week 2, Upstream data wasn't collected due to a technical fault)*

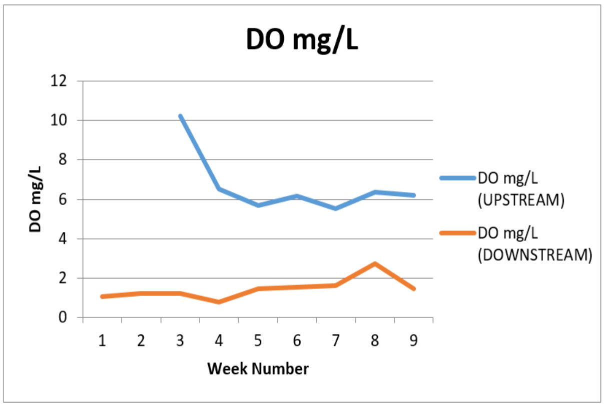



Figure 31. Line graph showing mean DO mg/L at upstream site and downstream site.
*(*Week 2, Upstream data wasn't collected due to technical fault)*

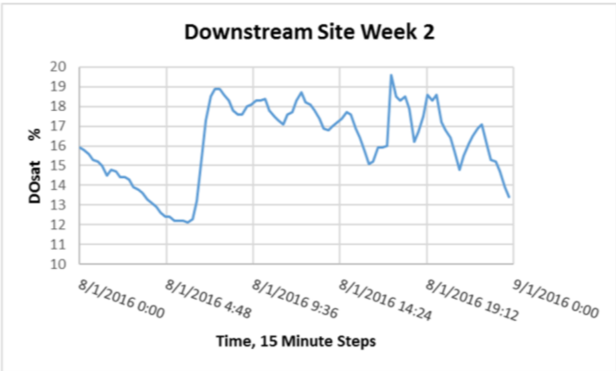



Figure 32. Line Graph showing daily (8/1/2016) DO sat % at downstream site

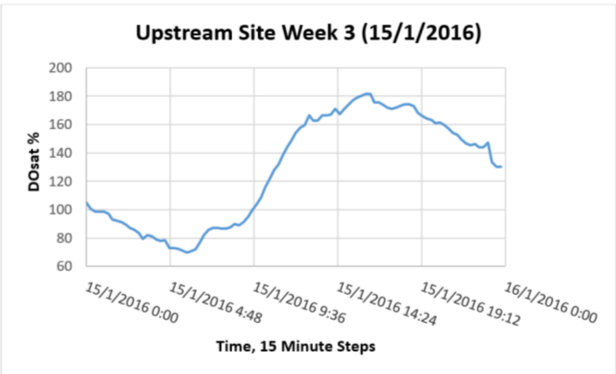



Figure 33. Line Graph showing daily (15/1/2016) DO sat % at upstream site

## 3.2.2 Comparing pH levels

From Figure 34, it can be seen that the upstream site had a slightly higher pH that is closer to the value 8 [*range: 7.8 - 8.0, excluding Week 1 anomalous data*]. The downstream site had a slightly lower pH value which is closer to 7, neutral value [*range: 7.0 - 7.5*].

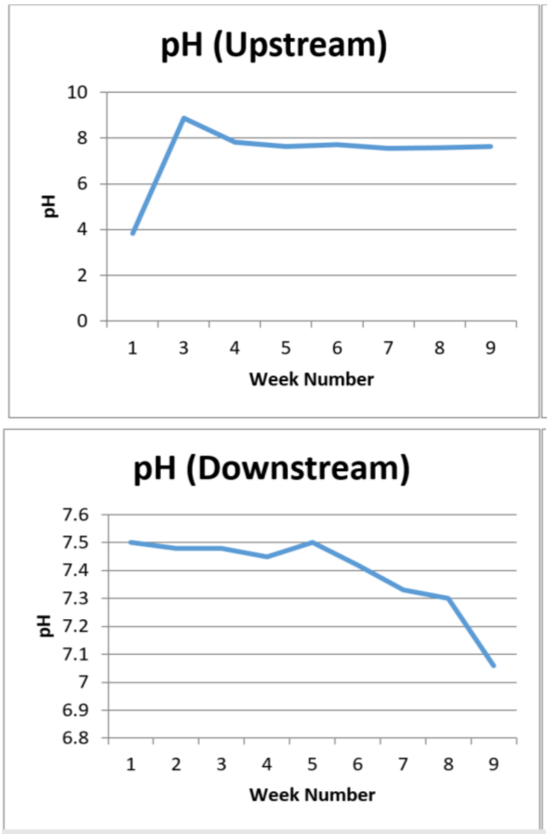



Figure 34. Line graph showing mean pH at upstream site and downstream site.
*(*Week 2, Upstream data wasn't collected due to a technical fault)*

### 3.2.3 Comparing turbidity

With reference to figure 35 below, the upstream site has a lower turbidity than the downstream one from Week 1 to 5. However, from week 6 to week 9, the downstream site has a lower turbidity than the upstream one.

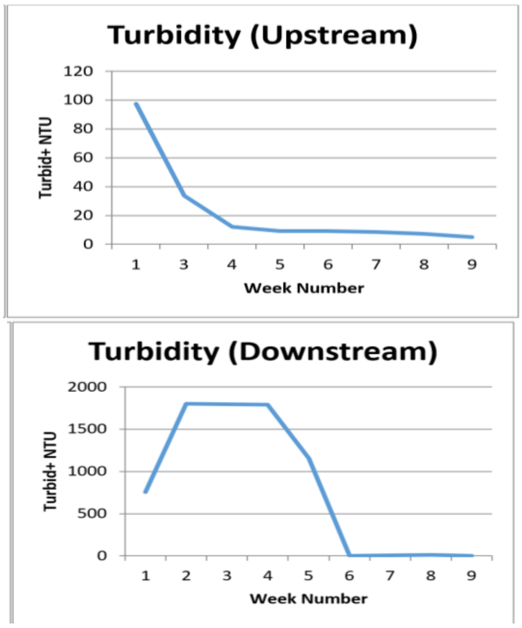



Figure 35. Line graph showing mean turbidity at upstream site and downstream site.
*(*Week 2, Upstream data wasn't collected due to a technical fault)*

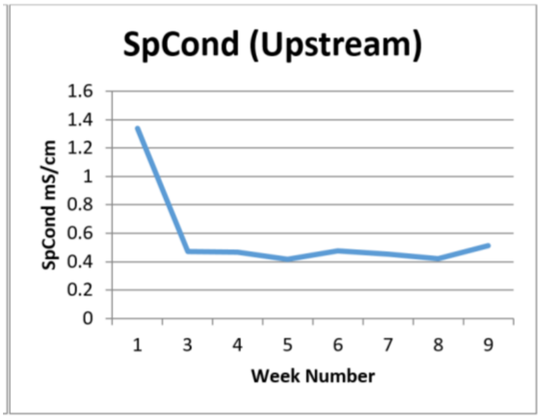
Comparing turbidity readings from Figure 35 and Table 5, the difference in the values of turbidity measured is significantly different. This could be due to data from Figure 35 being plotted from average turbidity values of the whole week while the data from Table 5 being taken on the spot at a particular timing and day.

Table 5. Mean turbidity of the 5 sites from Week 1 to 9

| Sites | Mean Turbidity/NTU Over 9 Weeks |
|---|---|
| Site 1 | 23 |
| Site 2 | 24 |
| Site 3 | 14 |
| Site 4 | 6 |
| Site 5 | 32 |

### 3.2.4 Comparing Specific Conductance (SpCond)

The upstream site had similar SpCond as the downstream site, with ranges between 0.4 and 0.6 mS/cm. The SpCond are relatively low throughout.
(*Refer to above 3.1.5 Comparing Total Dissolved Solids)*



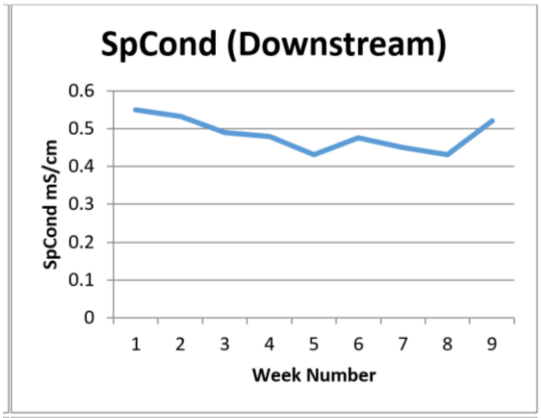




Figure 36. Line graph showing mean specific conductance at upstream site and downstream site.
*(*Week 2, Upstream data wasn't collected due to a technical fault)*

It is also expected that Site 3's water samples have low turbidity as Site 3 is the downstream site where

### 3.2.5 Comparing other factors (Temperature)

Both the upstream and downstream sites generally had average temperatures between 27 degrees Celsius and 31 degrees Celsius

# 4 Discussion

## 4.1 Nitrates and Phosphates

The little difference in nitrate and phosphate levels at sample sites may be attributed to two possible reasons - cleansing biotopes having minimum impacts on improving water nutrient levels or water nutrient levels are so low that there are little nutrients for biotopes to remove, with the latter being more probable. Therefore, data obtained is inconclusive with regards to the effectiveness of biotopes in improving nutrient levels of water but it can be said that the waters at JEG have relatively low nutrient levels.

The result of the biotope having minimum impact on improving water quality may be due to several factors, one prominent one includes the washing of sediments and nutrients into the water due to surface runoff. Singapore being geographically located at the equator, experiences high temperature and receives high amount of precipitation. Intense heating due to the insolation of sun results in high evapotranspiration and a low amount of water collected in biotopes. Water in the biotope will remain stagnant and unable to flow into the next cell of the biotope until rain falls. The rainfall will wash sediments from the nearby slopes into the water collected in the biotope. This will increase the amount of nutrients and turbidity of the water, affecting the accuracy of datas. It may then give rise to the image that the biotopes have minimum impact on improving the water quality.

However, it is a considerable that surface runoff does not result in significant runoff of phosphate nutrients, with phosphate as a component of fertilisers, as soil particles hold on to phosphate particles. Hence, there might be another factor for which the biotope has minimal impact on the water quality.

## 4.2 Turbidity

### 4.2.1 Turbidity Tube

Site 3 and Site 4 are generally more turbid as compared to the 3 other sites.

Site 2 is an upstream site near the grassy downward slopes. During rainfall, surface runoff from the slopes may carry sediments from the grassy slopes to the water at Site 2, hence, giving rise to the amount of sediments and turbidity of water in the site.

On the other hand, it is expected that Site 1's water samples have a higher turbidity as it is the area before the water undergoes treatment in the biotope. The clarity of water before entering the biotope should be theoretically, much worse than after it had gone through the biotope.
excessive runoff from the grass beds may result in increased levels of turbidity. This is due to the stirring up of

stormwater runoff which has been through filtration through cleansing biotopes would flow towards the underground cistern.

Site 4's water samples are surprisingly clear despite it being an upstream site. It had exceeded the turbidity tube's measurement of maximum 120cm 5 times in the span of 9 weeks. This may be due to storm water runoff from the nearby car park. The water is stained with oil leaks from the cars, but there is no researches to prove that there is a correlation between oil and the reduction of total suspended solids. Hence, since the water is mainly just made up of clear rainwater, there is not much sediments accumulated, giving rise to the clear water in Site 4.

During week 4, there was construction ongoing at the entrance of Jurong Eco-Garden. Although there were silt curtains which were supposed to control the flow of sediments, it was clear that it was not effective. After storm events in week 4, sediments were observed to be displaced down streams and along pathways. This could have attributed to the general decrease in turbidity in sites during week 4.


Figure 37. Cemented gap between barriers and ground

During week 5, the gaps between construction barriers and the ground were cemented and sediments were not observed to flow out from the construction site, as evidenced in figure 37. This could justify for the slight increase in turbidity for all sites in week 5.

## 4.2.2 YSI Data

The upstream site has a lower turbidity than the downstream one from Week 1 to 5. However, from week 6 to week 9, the downstream site has a lower turbidity than the upstream one. This observation could be attributed to Week 1 to 5 having more storms than from Week 6 to 9.

Comparing turbidity readings from the YSI and the turbidity tube, the difference in the values of turbidity measured is significantly different. This could be due to data from Figure 5 being plotted from average turbidity values of the whole week while the data from Table 5 being taken on the spot at a particular timing and day.

Turbidity levels vary with the increased number of human-related activities in the water body, it also varies with the weather condition of the day. Heavy storms or sediments on the streambeds as well as the soil/sediment runoff from the grass beds surrounding the water body. Sites 1, 2, 3 and 5 receive its source of water from the Nanyang Technological University (NTU) campus while Site 4 receives its source of water from the CleanTech Park. All in all, the results have shown that our hypothesis is true since Site 3 is the most turbid site, with the exception of Site 4 which receives its water source from a different location.

## 4.3 E. coli

Highest E. coli readings were observed at all five sites during Week 3 Storm and Week 4. This could be attributed to the storm events which occurred during fieldwork day during Week 3 Storm and a day before fieldwork during Week 4. Rainfall and its associated stormwater runoff have been linked to the transport of many pollutants into the 5 sites. Fecal material, from a variety of mammals (birds, livestock, and wildlife), can be washed into the sites following rainfall and resulting in exponential growth of e. coli.

Comparing the E. coli readings from Sites 1, 2, 3 and 5, with the exception of Site 4, Site 3 has the lowest E. coli readings consistently. Hence, the results proved our hypothesis to be true.

# 4.4 Dissolved Oxygen (DO)

## 4.4.1 CHEMets Kits

Very slight fluctuations in DO levels between sites could be due to the similar times of the day where water testing are conducted. Processes such as photosynthesis are prominent in raising dissolved oxygen levels to an average of 8 PPM. Hence, the cleansing biotopes seem to have little impact on DO levels. However, there are limitations due to wide range between DO levels that can be tested. A more reliable comparison between DO levels before and after the water has passed through the cleansing biotopes, at the upstream and downstream sites respectively, could be done based on the analysis of the dissolved oxygen data obtained from the YSI below.

Table 6. Water temperatures and the corresponding saturation concentration of oxygen in water.

| Water Temperature/ C° | Saturation concentration of oxygen in water/ DO mg/L |
|---|---|
| 22 | 8.8 |
| 24 | 8.5 |
| 26 | 8.2 |
| 28 | 8.0 |
| 30 | 7.6 |

All above dissolved oxygen tests were conducted using CHEMetrics Dissolved Oxygen Level Kits. These tests received gives rise to the small standard deviation of temperature.

were conducted for first four weeks and the DO levels tested at all 5 sites over the 5 different tests were high and similar. Therefore, there is no need for further kits testing of DO level at the five sites, and more since DO levels comparison can be done more accurately from the DO data obtained from the YSI.

### 4.4.2 YSI Data

High DO sat % could be due to the photosynthesis of phytoplankton which produces more oxygen in the waters while low DO sat % could be due to the presence of marine life such as koi fishes which respire and take in more dissolved oxygen, the decomposition of organic matter and the limited time water, which had just come through the biotope soil, had to become re-aerated with dissolved oxygen.

In other words, the higher the temperature of the water, which coincides with the temperature of the surrounding air, the lower the DO mg/L would be. Hence, for the days that have a lower temperature, the DO mg/L would naturally be higher (Week 3, Upstream & Week 8, Downstream), and the days that have a higher temperature, the DO mg/L will be lower (Week 5 and 7, Upstream & Week 4, Downstream)

## 4.5 pH

Upstream site has a higher pH closer to the value 8 while the downstream site has a slightly lower pH value which is closer to 7, neutral value. The largest variety of freshwater aquatic organisms prefer a pH range between 6.5 to 8.0 (Behar 1997). The data from above are hence in the acceptable range.

## 4.6 Total Dissolved Solids

Based on our hypothesis, we expected the total dissolved solids in Sites 1, 2, 4 and 5 to be higher than that in Site 3. This hypothesis is generally true with the exception of Site 4 having lower total dissolved solids as compared to the Site 3. Generally, Site 4 has the lowest amount of total dissolved solids amongst all sites, with the exception of Week 4 and 5.

### 4.7 Specific Conductance

Since SpCond are relatively low throughout at all sites, this shows that the amount of dissolved solids in the waters at JEG should be relatively low as well.

## 4.8 Temperature

Both the upstream and downstream sites generally had high average temperatures between 27 degrees Celsius and 31 degrees Celsius. This is because Singapore is located at the equator, where sunlight is received for 12 hours a day. The equal and consistent amount of sunlight

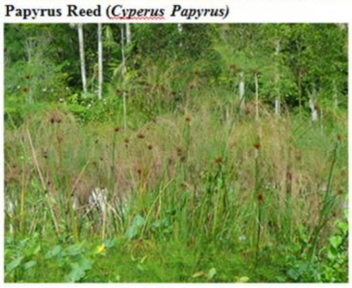
# 5 Proposed Improvements to JEG's Cleansing Biotope Design

## 5.1 Analysis of the Cleansing Biotope

From the water quality investigation conducted in the Jurong Eco-Garden, as well as field observations throughout the data collection period, the team concludes that the cleansing biotopes have not been able to perform their functions optimally.

The cleansing biotopes are structured as 3 adjacent cells arranged in a terraced manner, such that water draining into it at Site 1 is directed through each cell and supposedly subjected to biological and mechanical filtration 3 times. Each cell is planted with selected aquatic and sub-aquatic plants, as summarised in Table 7 below.

Table 7: Summary of flora identified at data collection sites

| | **Types of Plants present in each Site** |
|---|---|
| **Site 1** | **Emergent plants:**<br>• Water sprite (*Ceratopteris Thalictroides*)<br>• Powdery Thalia (*Thalia Dealbata*)<br>• Paper Reed (*Cyperus Papyrus*)<br><br>**Invasive plants:**<br>• Water convolvulus (*Ipomoea Aquatica*)<br> |
| **Site 2** | **Emergent plants:**<br>• Powdery Thalia (*Thalia Dealbata*)<br><br>• Papyrus Reed (*Cyperus Papyrus*)<br><br>• Dwarf Papyrus Reed (*Cyperus Haspan*) |

| | |
|---|---|
| |  • Swordplant (*Echinodorus palaefolius*) |
| |  **Invasive plants:** • Water convolvulus (*Ipomoea Aquatica*) |
| **Site 3** | **Fringe plants:** • Spider lily (Hymenocallis littoralis) <br> **Emergent plants:** • Powdery Thalia (*Thalia Dealbata*) • Paper Reed (*Cyperus Papyrus*) • Water banana (*Ludwigia adscendens*) <br> **Invasive plants:** • Water convolvulus (*Ipomoea Aquatica*) |
| **Site 4** | **Submerged Plants:** • Swordplant (*Echinodorus palaefolius*) • Algae |
| **Site 5** | **Emergent plants:** • Dwarf Paper Reed (*Cyperus Haspan*) • Cattail (*Typha Augustifolia*) |

It has been observed in the past few months of fieldwork, that the plants in JEG requires continuous maintenance. Workers are also seen trimming and removing weeds that had overrun the sites. Scenarios where high intensity rainfall caused emergents with weaker stems to topple over, lying limply over the low water level in cells of the biotope, were also seen frequently, namely at site 2.

Multiple reasons may account for the above concerns. The planting of the emergents may not be lush enough to allow the plants to be close enough to support each other, increasing the possibility of the toppling of the emergents. Also, the emergents may not have be fully grown and together with the unfavourable weather conditions, it resulted in the weaker stems being unable to withstand the high intensity storm events, eventually toppling over.

In response to these observations, the team proposes three key features for the cleansing biotope design:

**(1) Choice of water plants and density of planting,**

**(2) Honeycomb structure to support tall emergent plants and**

**(3) Multi-soil layering system beneath the cleansing biotopes.**

## 5.2 Improvements in Planting

Several improvements to the cells of the biotope may be made, primarily lusher planting. Floating plants like duckweeds may be added into the biotope as well to maximise the area coverage of plants on the water surface in the cell, for the maximum uptake of nutrients as well as to provide a more efficient natural filtration system. A variety of plants with different nutrient needs may be introduced to the biotope, while ensuring that the plants' need should complement each other, to prevent the competition for certain nutrients and the shortage of them.

**<u>Suggested plants:</u>**

- **Scouring Rush (Equisetum hyemale)**

The Scouring Rush (Equisetum hyemale) is best grown in wet soil under full sun, making it a good plant choice for the cleansing biotope. The rough bristles are used traditionally to scour and clean pots. It can also be used to shape the reed of reed instruments.

- **Umbrella Plant (Cyperus alternifolius)**

The Umbrella Plant (Cyperus alternifolius) is a rushlike aquatic species with its leaves arranged on the stems like an umbrella. It has the ability to absorb nitrogen and phosphorous rapidly, and is also able to accumulate copper and manganese. This plant can be grown all year round in a well-watered environment.

- **Purslane (Portulaca orleracea)**

The Purslane (Portulaca orleracea) has thick fleshy stalks and its flowers have a variation of colours, blooming only in the day. The plant can efficiently accumulate copper and remove endocrine disruptors (chemicals that interfere with the hormone system) from water.

- **Narrow leaf cattail (Typha angustifolia)**

Typha angustifolia, Narrow Leaf Cattails, are one of the most important native wetland plants, providing wildlife habitat, improving water quality and providing food for wildlife. Water quality is enhanced as Typha angustifolia absorb many nutrients from water and the colonies of plants can be an important way to trap silt entering waterways.

- **Canna glauca**

Canna glauca can be used to accumulate heavy metals such as zinc, lead and copper.

- **Epipremnum aureum** (Money plant)

It can remediate Bisphenol A (BPA), an endocrine-disrupting chemical

- **Ficus microcarpa** (woody plant species)

It removes heavy metal contaminants

- **Water hyacinth (**Eichhornia Crassipes)

Average N removal rate of 125.7 mg per plant and average P removal rate of 7.5 mg per plant

- **Macrophytes (rooted submerged and emergents)**

Macrophytes are aquatic plants that grow in or on the edge of saline and fresh water bodies. They can be either emergent, submergent or floating. Macrophytes are an important component in both natural and constructed wetlands as they provide food and shelter for fish, aquatic invertebrates and water birds. Most importantly, Macrophytes also aid in the removal of nutrients from stormwater runoff. The current biotope setup seems to be lacking in macrophyte species, the only apparent one being the swordplant (Echinodorus Palaefolius)

**Criteria for choice of plants:**

- Effective pollutant removal by filtration
- Sustain hydraulic conductivity of filter media
- Aesthetically pleasing
- Competes for nutrients in the water to control the growth of algae and invasive weeds
- Improves water quality by removing contaminants such as heavy metals

## 5.3 Honeycomb Structure

The honeycomb structure is designed to support tall emergent plants such as the Water sprite (Ceratopteris Thalictroides), Powdery Thalia (Thalia Dealbata), Paper Reed (Cyperus Papyrus) etc. The unique structure of the honeycomb allows the emergents to lean against the walls of the honeycomb-like structure for growth support. The current problem noticed at JEG was that the tall emergents, when planted into the cell without any form of structural support, toppled over easily and tended to block the floaters and submerged aquatic plants from getting adequate sunlight vital for healthy plant growth. Also, when viewed from the surroundings of the biotope, the emergents tended to get rather messy and not aesthetically pleasing

The honeycomb structure is also constructionally stable and aesthetically pleasing to the eye. These honeycomb cells are to be constructed in the middle of the cell site so as to prevent blockage of sunlight for the submerged plants and floaters and for the public to clearly view the varied plants capable of water filtration without any invasion. The material of the honeycomb structure is proposed to be polyvinyl chloride (PVC) which is known for its rigid, flexible and cost effective features. Figure 38 illustrates the proposed structure and implementation of the honeycomb.

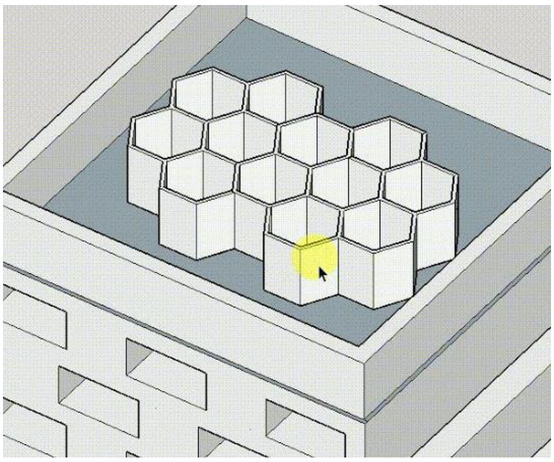


Figure 38. Honeycomb support for emergent plants.

## 5.4 Multi-Soil Layering System

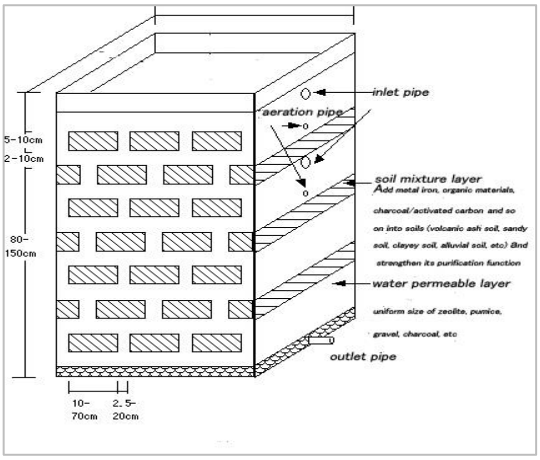



Figure 39. Structure of Multi-Soil Layering System (Sato, Wakatsuki, 2010)

Multi-Soil Layering (MSL) systems are designed for municipal wastewater, livestock wastewater and polluted river mechanical water treatments (Ho, Wang, 2015). These systems require low maintenance and yet have high stable treatment performance against fluctuation of raw water.

MSL systems consist of the soil mixture layer (SML) arranged in a brick-like pattern and surrounded by alternate permeable layers (PL), as shown in figure 39 (Sato , Iwashima , Matsumoto, Wakatsuki, Tsugiyuki Masunaga, 2010). This arrangement of the SML improves water permeability while that of PL allows a high hydraulic loading rate (Sato el at.,2010). Addition of substances, such as activated carbon, zeolite and charcoal, which act as bio-filters, help increase the filtration within the soil. Bio-filters are covered with biofilms which breakdown nutrients such as phosphate, nitrate and organic carbon, on top of filtering contaminants in the input water (Kloc, González, 2012). Aerobic conditions occur in the zeolite, and anaerobic conditions in the saturated soil blocks (Luanmanee, Attanandana, Masunaga, Wakatsuki). This mixture of aerobic and anaerobic conditions allows for the efficient purification of wastewater (Kloc, et at., 2010). Table 8 below outlines the proposed materials to be used for the SML.

Table 8. Materials for MSL Systems (Sato, et al., 2010)

| Proposed Substance | Key Characteristics | Proposed Site For Implementation In System |
|---|---|---|
| **Charcoal*** | • High porosity<br>• Hydrophobic adsorbent<br>• Habitat of microorganisms | Soil Mixture Layer |
| **Sandy Soil** | • Low cost<br>• Large particle size and high permeability on-site | Soil Mixture Layer |
| **Granular Activated Carbon*** | • Low cost<br>• Environmentally friendly - obtained from any organic material with high carbon content<br>• Large surface area for microorganism growth and development | Permeable Layer |
| **Zeolite** | • High NH4+ adsorption ability<br>• High cation exchange capacity<br>• High porosity | Permeable Layer |

*A series of indoor tests indicated that the suspended solid (SS) removal efficiency of granular activated carbon was between 76.2% and 94.6%; while that of zeolite achieved efficiencies between 53.7% and 87.4%. The zeolite system and granular activated carbon system also demonstrated a stable NH3-N removal performance at 92.3%-99.8% (Ho, Wang, 2015).

In response to the high level of turbidity, the team proposes that MSL be considered in the enhanced design of the cleansing biotope. While it is conceivably difficult to modify the current structure at JEG without tearing and rebuilding the whole thing, the learning point is that cleansing biotopes cannot solely depend on surface planting to carry out the full range of filtration and cleansing functions. A proposed implementation scheme is visualised in figure 40 below.

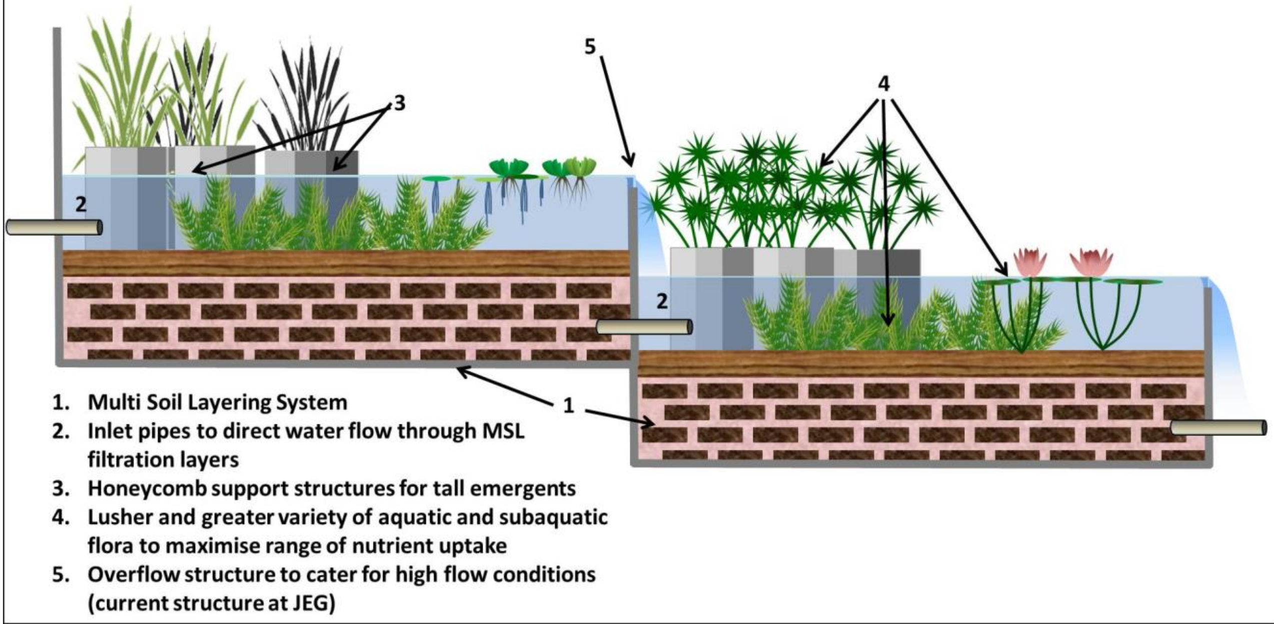



Figure 41. Proposed Improvements to Cleansing Biotope Design.

# 6 Conclusion

Our research project aims to examine if the current configurations of cleansing biotopes in Jurong Eco-Garden are effective in the treatment of water. The team expected the indicators of water quality (Nitrates, Phosphates, pH, E. coli, Specific Conductance, Turbidity and Temperature) to be lower downstream of the cleansing biotope cells (with the exception of Dissolved Oxygen) if the cleansing biotopes fulfils their functions ideally.

Our findings did not reflect this perfectly due to factors such as weather conditions and variation in land use upstream. Nevertheless, the findings do suggest the cleansing biotopes are not functioning as well as it was expected to be. Given the limitations of time and resource, the team proposed improvements to the designs of the cleansing biotopes which could potentially help the biotopes to perform its functions more optimally.

# 7 Areas for Further Study

## 7.1 Bishan Ang Mo Kio (PUB, 2010)

Kallang River@ Bishan-Ang Mo Kio Park is a collaboration between PUB and the National Parks Board. The design concept was to integrate the park with the river, to bring park users closer to the water so they can enjoy it while appreciating the importance of clean water. There are cleansing biotopes upstream of Kallang River. Water is pumped from the river and the ponds within the park into the cells of the biotope, where it is filtered by plants and filter media before being returned to the ponds and eventually the river. Part of the treated water undergoes ultraviolet disinfection and is supplied to a nearby water playground. The team believes that the study of the Bishan-Ang Mo Kio Park will enhance our understanding of the performance of cleansing biotopes contextualised in Singapore.

## 7.2 River Valley High School

The team envisions bringing the study of the cleansing biotopes into the team's school compound. A prototype of a cleansing biotope installed in the school pond enables the team to be able to conduct more frequent data collections under more controlled conditions. This study will empower the team to further study the performance of cleansing biotopes installed in Singapore and investigate the possibilities of sustaining such a green feature in the school pond.

As Singapore's population grow and the pace of urbanisation continues, the team believes that strategies such as cleansing biotopes will become more necessary in the future. Hence, studies of cleansing biotopes are of great value to the Singapore's environmental field as the country looks into implementing green features into major water bodies to enhance and maximise its water resource through cleaning and conserving flows from precipitations.

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