ANALYSIS OF WATER QUALITY IN UNIVERSITY MALAYA RAINWATER HARVESTING SYSTEM

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ABSTRACT

The aim of this study is to identify the condition of tanks located in the residential college and main building in University of Malaya and analyze water quality inside five chosen sample Rainwater Harvesting System (RWHS) tanks. The parameters analysed are compared with the National Water Quality Standards Malaysia (NWQS). The parameters that are measured in the study are temperature, pH, , total suspended solid (TSS), dissolved oxygen (DO), biological oxygen demand (BOD), chemical oxygen demand (COD) and ammoniacal nitrogen (NH_3-N). The study showed that all parameters are between class I and III by National Water Quality Standards Malaysia (NWQS). The results showed that temperature, pH, TSS, DO, BOD, COD and NH_3-N average values are 25.8°C-27.0°C, 5.82-7.02, 2.05-3.81mg/L, 5.4-7.3 mg/L, 1.34-1.43mg/L, 3.45-6.34 mg/L and 0.33-0.76 mg/L, respectively. The study highlighted good conditions and poor conditions of total 63 RWHS tanks in University Malaya and that there is a need to improve the condition of tanks. There are two poor conditions RWHS tanks, which are Kompleks Perdana Siswa UM (KPS) Tank A and Kinabalu Residential College (KK8) Tank A that unusable because of missing and broken pipes and not functioning in collecting rainwater. Therefore, prompt action needed for repair and maintenance work. 61 RWHS tanks are in good condition which it has good water flow and no broken parts. However, maintenance still in need to ensure good water quality and sustainable system. Control measures are introduced based on the interview method and observation from the field investigation as to ensure sustainable RWHS in University Malaya. This study also provides recommendations such as cleaning program and visual artwork to develop an awareness to use recycle water among University Malaya communities, hence the important of RWHS for sustainable environment.

Keywords: Rainwater Harvesting System, Water Quality, University Malaya

ABSTRAK

Tujuan kajian ini adalah untuk mengenalpasti keadaan tangki yang terdapat di kolej kediaman dan bangunan utama di Universiti Malaya dan menganalisis kualiti air di dalam lima tangki Sistem Penuaian Air Tawar (Rainwater Harvesting System) (RWHS) yang dipilih. Parameter yang dianalisis dibandingkan dengan Standard Kualiti Air Negara Malaysia (NWQS). Parameter yang diukur dalam kajian ialah suhu, pH, total pepejal terampai (TSS), oksigen terlarut (DO), permintaan oksigen biologi (BOD), permintaan oksigen kimia (COD) dan nitrogen amoniak (NH3-N). Kajian menunjukkan bahawa semua parameter antara kelas I dan III oleh Standard Kualiti Air Negara Malaysia (NWQS). Nilai-nilai purata suhu, pH, TSS, DO, BOD, COD dan NH3-N adalah 25.8 ° C-27.0 ° C, 5.82-7.02, 2.05-3.81mg / L, 5.4-7.3 mg / L, 1.34- 1.43mg / L, 3.45-6.34 mg / L dan 0.33-0.76 mg / L, masing-masing. Kajian ini menyerlahkan keadaan baik dan kurang baik daripada 63 tangki RWHS di Universiti Malaya dan terdapat keperluan untuk meningkatkan keadaan tangki. Terdapat dua tangki RWHS yang kurang baik iaitu Kompleks Perdana Siswa UM (KPS) Tank A dan Kolej Kediaman Kinabalu (KK8) Tank A yang tidak dapat digunakan kerana paip yang hilang dan patah dan tidak berfungsi dalam mengumpul air hujan. Oleh itu, tindakan segera diperlukan untuk kerja pembaikan dan penyelenggaraan. 61 tangki RWHS berada dalam keadaan baik yang mempunyai aliran air yang baik dan tiada bahagian yang patah. Walau bagaimanapun, penyelenggaraan masih diperlukan untuk memastikan kualiti air yang baik dan sistem yang mampan. Langkah-langkah kawalan diperkenalkan berdasarkan kaedah wawancara dan pemerhatian dari penyiasatan lapangan untuk memastikan RWHS yang mampan di Universiti Malaya. Kajian ini juga memberi cadangan seperti program pembersihan dan karya visual untuk membangunkan kesedaran untuk menggunakan air kitar semula di

kalangan masyarakat Universiti Malaya, oleh itu pentingnya RWHS untuk persekitaran yang mampan.

Keywords: Penuaian Air Hujan, Kualiti Air, Universiti Malaya

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Hasifa Hashim

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LIST OF SYMBOLS AND ABBREVIATIONS

RWHS	:	Rainwater Harvesting System
UM	:	University Malaya
NAHRIM	:	National Hydraulic Research Institute of Malaysia
MHLG	:	Minister of Housing and Local Government
SPAN	:	National Water Services Commission
SIRIM	:	Standards and Industrial Research Institute of Malaysia (SIRIM)
BOD	:	Biochemical Oxygen Demand,
NH_3-N	:	Ammoniacal Nitrogen
DO	:	Dissolve oxygen
COD	:	Chemical Oxygen Demand
TSS	:	Total suspended solid
JPPHB	:	Jabatan Pembanggunan & Penyelenggaraan Harta Benda

LIST OF APPENDICES

CHAPTER 1: INTRODUCTION

1.1 Background

Human, cities, industries and agriculture depend on water religiously and the growing demand is never going to slow down. Three quarters of the earth is covered with water but only 2.5 per cent is fresh water and less than 1 per cent is available to sustain all terrestrial life and ecosystems. According to the United Nation Secretary-General Antonio Guterres, less than 2 billion people lack of access to safe water (Lederer, 2018). Therefore, it is important conserving water to create sustainable environment.

In Malaysia, Rainwater Harvesting System (RWHS) policy started when the government together with various government agencies such as National Hydraulic Research Institute of Malaysia (NAHRIM) and other universities include University Malaya (UM) to be involved with research and development of RWHS. RWHS is one of the environmental projects under water warriors project in UM. The program has started on 2012 with a mission of conservation and rehabilitation water bodies in UM campus.

Rainwater harvesting technology application is to collect and store natural precipitation with an aim to reduce amount of water usage thus to secure precious water resource. The system facilitates the need of clean water in everyday life. Implementation of rain harvesting system in UM has developed 63 tanks located at 25 different locations in the campus. Total volume of collected water can reach to 36,013.52 gallons. (UM Living Lab (Water Warriors), 2019).

Rainwater harvesting has various applicable functions for every UM community such as cleaning, irrigation for plants, ablution for Muslim, domestic consumption and other external uses. Research shows that UM have reduced water consumption from pipe supply at least more than 17% in 2017 (UM Living Lab (Water Warriors), 2019).

The condition of the tanks must be look after and manage to ensure continuous consumption and the tank functioning well. Continuous monitoring water quality is crucial to track maintenance performance of the system and ensure the safety of water usage and storage. Building awareness about the importance of saving and conserve water and RWHS to be widely practiced in country is crucial, ensuring people to be alarm and concern about environment.

University Malaya has participating in the international sustainability program known as Universitas Indonesia Green Metric World University Ranking (UIGM) and has reached its highest record in 2017. This research is one of the opportunities in educating future generation and help in promoting UM ranking in UIGM.

Therefore, this research focuses on identifying the condition of Rainwater Harvesting System tanks in University of Malaya. Field investigation and observation is done on the RWHS tanks. Parameters water quality of five chosen tanks will be analyze and compare with the National Water Quality Standard to determine it classes. Interview regarding on the maintenance of the RWHS tanks in UM is done to suggests control measures on developing awareness among students and community in UM about the RWHS. From the research, recommendation in developing awareness of RWHS will be propose.

1.2 Scope of the Study

This study is focus on the RWHS tanks scattered in UM. Field survey is done to investigate the condition of tanks located in the residential college and main building in University of Malaya. Five different tanks of harvested rainwater samples that located in Tunku Abdul Rahman Residential College, Ibnu Sina Residential College, Za`ba Residential College, Kinabalu Residential College and Tun Ahmad Zaidi Residential College are chosen to be taken for water quality analysis. The study is focus on physico-chemical properties to determine the average water quality in each tank and determine it classes. The time of samples collection will be done from April until June during daylight.

1.3 Problem Statement

Severe water crisis, which had affected few areas in Kuala Lumpur and other states in Malaysia in the past few years have become a reminder for people to concern for water. Needs and various activities involving water has caused increasing in water consumption. Malaysia is gifts with an abundant rainfall and frequent throughout the year, however lack of water management may cause urban flooding and water scarcity. Rainwater Harvesting System (RWHS) may not be popular among Malaysian even though it has been introduced since 1988.

RWHS has been implemented in UM since 2012. Few tanks have been placed throughout UM in order to collect the rainfall. There are few tanks that have been actively used and also least active. Hence, the condition of each of the tank may also differ. It is significant to investigate and identify those tanks at different buildings or area in order to ensure the collected rainfall is fully utilizes for any purposes.

Water quality is an important parameter that must be monitor for human`s health and ecosystem. It is important task for the university to ensure the collected rainwater is free from pollution thus ensuring the system is properly maintained.

This study includes in identifying the state of each tanks. Observation on the area is done to study, activities in the RWHS areas and tanks location to suggest recommendation. Laboratory analysis will be conducted to determine the water quality parameters. Parameters include pH, temperature, Dissolved Oxygen, Biochemical Oxygen Demand, Chemical Oxygen Demand, Total Suspended Solids, and Ammoniacal Nitrogen will be compared with NWQS to determine it classes. Interview is also conducted to investigate on the maintenance of RWHS, thus propose on control measures to improve the system. Hence, recommendation on developing awareness among UM communities on the importance of RWHS to a sustainable living.

1.4 Objective of the Study

The aim of this research is to reduce water consumption in University Malaya and creates awareness among students and community in Rainwater Harvesting System (RWHS) in University of Malaya further to promote sustainable water resources in the future.

1. To identify the condition of tanks located in the residential college and main building in University of Malaya.
2. To analyze water quality inside five chosen sample tanks based on physicochemical parameters include pH, temperature, Dissolved Oxygen, Biochemical Oxygen Demand, Chemical Oxygen Demand, Total Suspended Solids and Ammoniacal Nitrogen and determine it classes based on NWQS.
3. To propose on the control measures for Sustainable RWHS System based on the interview on the maintenance of RWHS in UM
4. To proposed recommendation on developing awareness on RWHS among UM communities based on the field investigation and observation.

1.5 Significant of Study

The application of RWHS is not widely spread in Malaysia. However, there are some institutions including University of Malaya that have use the system in order to save water and environment. Water Quality determination is important to detect rainwater collected is either contaminated or vice versa.

The results of this study are expected to help to investigate the conditions of RWHS tanks in University of Malaya. On the other hand, the determination of water quality on the selected tanks will help in identifying their safety uses for any purposes. Hence, it is expected to be information for university and agency for further research. Finally, it may assist students and community to understand more about RWHS and increase awareness on the system for sustainable environment.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction of RWHS

Rainwater harvesting is directly by collecting from the roof stored before it can be used for domestic purposes **(**Zreig, Ababneh, & Abdullah, 2019; Tan et al., 2018; Asman et al., 2017; Abdullah & Al-Shareef, 2009). Malaysia has tropical weather and often humid and undergoes heavy rainfall from March to April and September to November with an average 1151-5687 mm a year (Tan et al., 2018). Unfortunately, high demand from industries, agricultures, household, increasing population and global warming still may cause water deficiencies in the future (Lederer, 2018; Tan et al., 2018). Malaysia has developed various low water supply technology that one of it is Rainwater Harvesting System (RWHS) to provide consumers with safe water supply (Zreig, Ababneh, & Abdullah, 2019; Asman et al., 2017; Gwenzi et al., 2015). It is suitable to be used as an alternative water supply (Kisakye & Van der Bruggen, 2018; Muriu-Ng'ang'a, Mucheru-Muna, Waswa, & Mairura, 2017) and there has been an interest and demand to make RWHS as a water supply system in urbanized area (Wurthmann, 2019). In facts there are report from countries such as Germany, Australia and Brazil that have proved to show significant water saving from using the system (Lani et al., 2018; Abdullah & Al-Shareef, 2009).

According to Wurthmann (2019), various study has been reported from 2009 until 2018 that replacing from potable water to rainwater harvesting system (Shaheed & Mohtar, 2015), countries like Beijing able to save water demand up to 25%, more than 30% in Australia and 2-100% across USA especially in the central and eastern USA. The system may still not popular among communities in Malaysia (Hamid & Nordin, 2011), as most of the dwellings developed have not been built with the system by the developer. However it has been applied for various types of buildings such as institutional and commercial (Lani et al., 2018).

2.2 Benefit on the Environment

The system is suitable in any dry or wet region and area with an absence of fresh water or groundwater, hence it is an economical small-scale technology with providing safe water supply (Asman et al., 2017;Gwenzi., 2015). It may be small but it is productive system for local environment with low maintenance costs and with the cooperation from the community to implement the RWHS, water, energy and money can be save (Abdulla & Al-Shareef, 2009; Sazakli, Alexopoulos, & Leotsinidis, 2007).

Excellent water management in Rainwater harvesting technology is crucial in order to prevent urban flooding and soil erosion in the city (Torres et al., 2019; Nosrati, 2017). Storm water usually occurs in the city of Kuala Lumpur after a short amount of time heavy rain and damage to the surrounding areas and waterways due to soil erosion (Lani et al., 2018; Sultana et al., 2016). Big water drainage system is built to prevent flood. For university with limited space not only has to be burden with water storage facilities to occupy the need of the

community, having more dam may cause ecological damage to the environment. Hence, direct water catchment, RWHS can reduce reliance on the dam (Lee et al., 2016).

2.3 Rainwater Harvesting System in Malaysia

Lani et al. (2018) & Lee et al. (2016) stated Malaysia has encountered severe water crisis in 1998 therefore in the following year, government has promoted a government building and house design to be included with facility for collecting rainwater.

Minister of Housing and Local Government (MHLG) created the first policy of rainwater harvesting in Malaysia on Guideline on Installing a Rainwater Collection and Utilization System to provide favorable buffer in times of emergency or insufficiency within the water. Following years, various agencies have present guidelines and policies to open the door the execution of RWHS in Malaysia. Japan has executed Rainwater Harvesting in public area and private buildings with the support from local authorities in the early 1980 for a solution water scarcity and urban flood. (Campisano, et al., 2017)

In the early implementation of RWHS in Malaysia, the system is not popular among the community (Lee et al., 2016). Poor introduction or campaign to the new system making it difficult to be well known and the system is not compulsory though it is encouraged to have in their property, and it is only developed in a certain new housing development. Government agency such as National Hydraulic Research Institute of Malaysia (NAHRIM) that is found in 2004 has executed RWHS project in double storey terrace house in few locations

in Kuala Lumpur, mosque and schools shown their efforts for the RWHS to make it mark (Hamid & Nordin, 2011).

In 2005, establishment of laws related to the water services industry, Water Services Industry Act 2006 and Water Services Commission Act 2006 is another effort by the government to encouraged RWHS implementation. Continue in the following year, RWHS applied to be mandatory to large buildings and government has forced under Uniform Building By-Laws 1984 in installation of RWHS in residential building and to all type of building with roof area equal or more 100 m^2 in all peninsular state and federal territories. (Rahman, Othman, Khalid, & Shawahid, 2013)

In 2013, the guideline on Installing a Rainwater Collection and Utilization System 1999 is revised and more stringent (Abdul Ghani, Mohamad, & Hui, 2016) to ensure the equipment is following standard approved by Standards and Industrial Research Institute of Malaysia (SIRIM) and National Water Services Commission (SPAN) and developers to comply the condition to install RWHS (Lee et al., 2016).

Malaysia may has properly execute the system in national level, however it is crucial for all the community to be involves by ensuring developers to install proper RWHS in their new housing project and efforts by citizens to have the system in their property thus ensuring water sustainability and saving our water resources.

2.4 Contaminants in Rainwater Harvesting system Tank

Previous research stated roof runoff contaminated by physical, chemical and biological contaminations (Zreig, Ababneh, & Abdullah, 2019). For examples organic matter, nutrients, organic compound, weathering of roof material and the leaching of the accumulated particulate organic matter and flora on roof surfaces (Nosrati, 2017; Gwenzi et al., 2015). These contaminants in roof water are likely depend on the source, anthropogenic activities and the flow pathways and their actions with the environment.

Figure 2.4 RWHS Tank in University Malaya

2.5 Analyze of Rainwater Quality

Water quality assessment is a productive management to prevent and control water pollution (Li & Liu, 2018; Karatayev et al., 2017; Othman et al., 2012) and the quality of rainwater is essential in order to determine its appropriateness for various uses. High population density, rapid industrialization and

urbanization, habitat destruction and wastewater disposal have cause damaged on ecosystem services that in the end cause human beings to suffer for their sustainable living (Alam et al., 2017; Rahaman et al., 2017; Mishra et al., 2017). Periodic monitoring water quality parameters are crucial to provide essential information of sustainable environment (Li & Liu, 2018; Alam et al., 2017; Ismail et al., 2014) and previous study has suggested untreated collected rainwater could be contaminated hence, produce risks to consumers (Zreig, Ababneh, & Abdullah, 2019; Gwenzi et al., 2015). The physicochemical parameters are measured and classified based on the National Water Quality Standard (NWQS) (Malaysia) to identify the effects of anthropogenic activities on water quality (Gafri et al., 2018; Li & Liu, 2018; Othman et al., 2012).

2.5.1 Water Quality Method and Instrument

Table 2.5.1 Water Quality Method and Instrument

Parameters	Standardize method	Instrument	References
Temperature (°C)	**Electrometric**	pH meter (model Hanna HI 2211) Eutech Instrument pH510	Gafri et al (2018) Asman et al (2017)

pH	**Electrometric**	pH Meter (model Hanna HI 2211) Eutech Instrument pH510	Asman et al (2017), Kazem (2017), H Kasmin et al (2016)
Dissolve oxygen	**Electrometric**	Dissolve Oxygen Meter (model YSI 5000)	Gafri et al (2018)
Total suspended solid		DR/890 colorimeter (HACH)	Gafri et al (2018)
Biochemical oxygen demand (BOD)	**BOD_5**	Dissolve Oxygen Meter (model YSI 5000)	Asman et al (2017)
Chemical oxygen demand (COD)		HI83099 Multipara Meter Lab-Photometer HACH DRB 200	Gafri et al (2018)

Ammoniacal Nitrogen (NH3-N)	HI83099 Multipara Meter Lab-Photometer.	Gafri et al (2018)

2.6 Water Quality Parameters

Biological oxygen demand (BOD), chemical oxygen demand (COD), Total suspended solid (TSS), Dissolved Oxygen (DO) and Ammoniacal Nitrogen (NH_3-N) measured as an indicators of water quality (Alam et al., 2017; Gafri et al., 2018; Li & Liu, 2018). DO and BOD are widely used as an indicator in water pollution and help in determine acceptable maximum pollution loads.

DO values is the volume of confined oxygen in water and it is crucial for microorganism to decompose waste substance. Low value reading of DO concentration is one of the problems that can affect water quality (Li & Liu, 2018). pH is crucial in water quality measurement to determine whether a solution is acidic or alkaline.

COD quantify the amount of organics in the water for example application in quantifying the amount of oxidize pollutants found in water. Water temperature can be alternate from human activities include industrial effluent and it is channel with toxic absorption and dissolved oxygen. (Karatayev et al., 2017; Li & Liu, 2018)

According to Nosrati (2017), analyzing RHWS is crucial since the management and control of RWHS is inadequate. Water quality can be classified according to the following classes (Gafri et al., 2018; Mood et al., 2017; Sultana et al., 2016; Ismail et al., 2014).

Table 2.6 Classes of National Water Quality Standards for Malaysia

Parameter	Unit	Class					
		I	IIA	IIB	III	IV	V
BOD	mg/l	1	3	3	6	12	>12
COD	mg/l	10	25	25	50	100	>100
DO	mg/l	7	5-7	5-7	3-5	<3	<1
NH_3N	mg/l	0.1	0.3	0.3	0.9	2.7	>2.7
pH		6.5-8.5	6-9	6-9	5-9	5-9	-
TSS	mg/l	25	50	50	150	300	300

NH_3-N=Ammoniacal Nitrogen, BOD=Biochemical Oxygen Demand, COD=Chemical Oxygen Demand, DO=Dissolve oxygen, TSS, Total suspended solid

2.7 Sampling Methods for Physicochemical Analysis

Physicochemical analysis results are of no value if the tested samples are not collected and stored properly. This has significant implications for sampling regimes, sampling procedures and sample preservation and storage methods. The water is placed in a cleaned polyethylene bottles and temperature 4 ^{o}C is recommended for the bottle to be stored and placed in the dark before laboratory analysis (WHO, 2017). The bottles of the sample must be clean. The time between the sample and analysis should generally be kept to a minimum. pH, temperature and DO must be tested immediately after the sample has been stored and transported back to the analysis laboratory (WHO, 2017).

2.8 Qualitative Method

This method is constructs findings without dependence on quantitative measurement or statistical data. It is commonly involving individual, group interview and observations approaches. From the implementation of the method, it able to explain what is happening and why, therefore problem could be investigated and solved (Hamilton & Finley, 2019).

2.9 Sustainability of RWHS

Amount of rainwater collection in certain location shows how well the system and analyzing the contamination from tank material, roof catchment surface and water loss are significance to determine the sustainability of RWHS (Alim, et al., 2019), therefore frequent and on schedule maintenance is necessary to ensure long life of the system.

CHAPTER 3: METHODOLOGY

3.1 Study Area

Table 3.1 Picture of the "red cloud" shows the sampling point of rainwater harvesting tanks located in University of Malaya

The experiment was conducted from April 2019 to June 2019 with three times sampling at University of Malaya of five tanks located in different residential college as shown in figure 3.1. There are 63 tanks located at 24 different locations in the campus. The selected 5 sample tanks for are shown in the map. University of Malaya located in the southwest of Kuala Lumpur (Gafri et al., 2018; Mood et al., 2017). Temperature in Klang Valley is 26.8-27°C monthly mean near uniform with high humidity 63-68% (Ramakreshnan et al., 2019). There are two seasons in Kuala Lumpur, which are wet season, northeast monsoon from November until March and dry season from June until September (Abdul Ghani et al., 2016; Ramakreshnan et al., 2019).

3.2 Design of Experiment

3.2.1 Field Investigation and observation Method

Observations of 63 tanks located in the residential college and main building in University of Malaya is investigated to identify the condition each of RWHS tanks. The locations of the tanks and activity in the RWHS tanks area are taken into account.

3.2.2 Analysis of Water Quality

Five sample RWHS tanks of different location were selected for water quality analysis. Three times sampling activity are conduct from April 2019 until June 2019. Below are justifications on why the RWHS tank has been choose:

1. Sample tanks from Tunku Abdul Rahman Residential College, Ibnu Sina Residential College, Za`ba Residential College and Tun Ahmad Zaidi Residential College situated in the accessible area for students where it is considered as an active tank. However, sample RWHS tank from Kinabalu Residential College situated in the isolated area where it is considered as least active tank.
2. Sample tank from Tunku Abdul Rahman Residential College, Ibnu Sina Residential College, Za`ba Residential College and Kinabalu Residential College situated in the open space where the catchment area are on the roof building on the other hand, Tun Ahmad Zaidi Residential College situated under the trees and the catchment area is on the vehicles' roof.
3. All the sample RWHS tanks are accessible to do sample collection.

Table 3.2.2 Summary of sample collection

Label	Location	Tank
C1	Tunku Abdul Rahman Residential College	B
C2	Ibnu Sina Residential College	B
C3	Za`ba Residential College	B
C4	Kinabalu Residential College	B
C5	Tun Ahmad Zaidi Residential College	A

Figure 3.2.2 (a) Left side of the picture is tank B from Ibnu Sina Residential College and the right side of the picture is tank B from Tunku Abdul Rahman Residential College

Figure 3.2.2 (b) Left side of the picture is tank B from Kinabalu Residential College and the right side of the picture is tank B from Za`ba Residential College

Table 3.2.2 (c)Tank A from Tun Ahmad Zaidi Residential College

3.2.3 Interview Method

Interview on the personnel in regards on the maintenance of RWHS is investigated to get more perspective and knowledge in detailed on it schedule and inspection. Therefore, control measures can be suggested to improve the system, thus creating awareness on the system for sustainable environment.

3.3 Research Flow

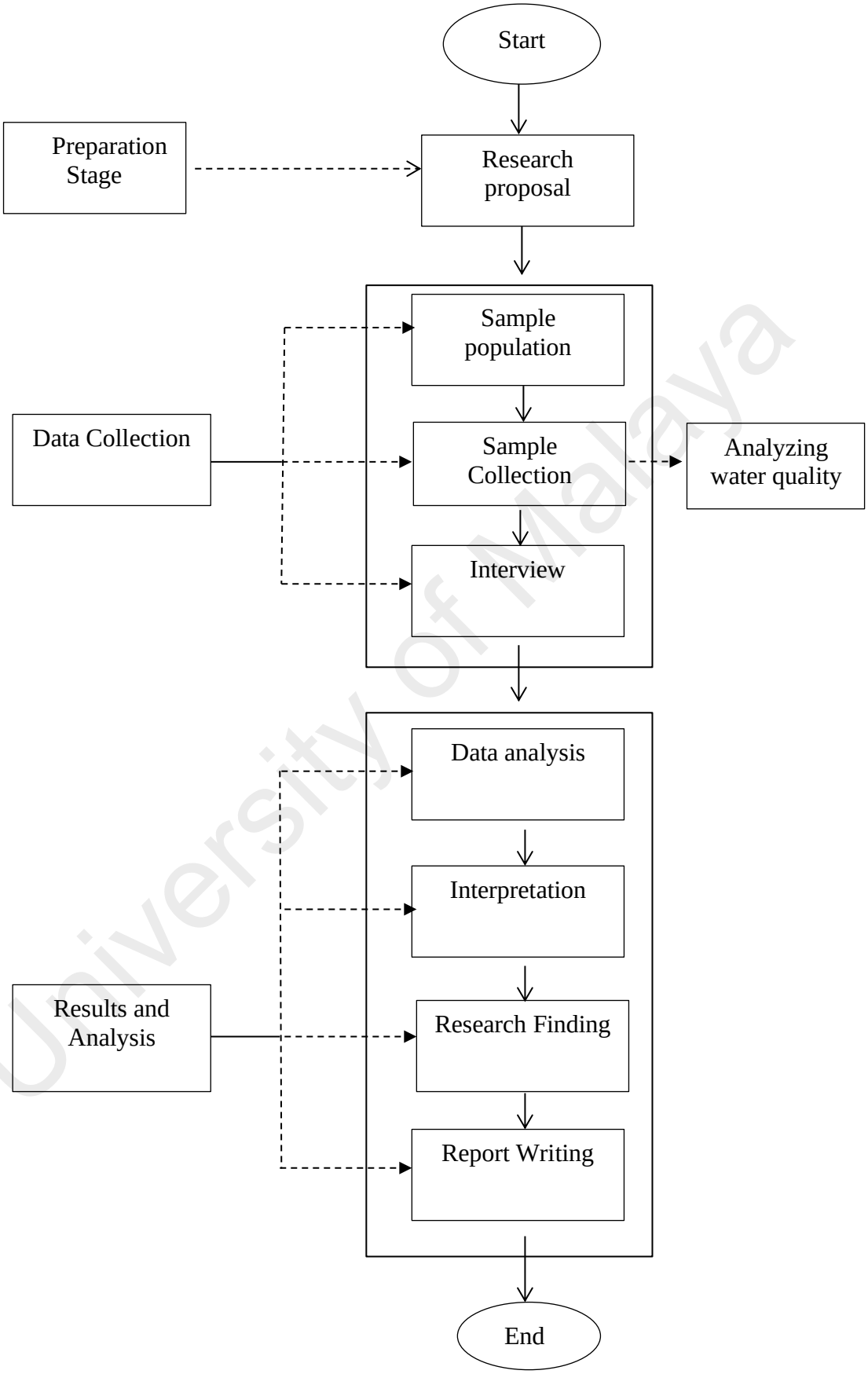

Figure 3.3 Research Flow

3.4 Collection of water samples

1L plastic polyethylene bottles are used to collect water samples are cleaned and washed thoroughly with tap water and then shake with deionized water. Before the sample taken, the tap is cleaned and removed from any attachment that may cause splashed. Clean clove is used to wipe the outlet to remove any dirt. The tap is open until it reaches it maximum flow for one minute to clean the surface line. Then, the metal spout is sterilized with portable lighter. The tap is open again to allow the water flow for one minute at normal rate flow. The bottle then mixed with the sample water prior it is filled in and label with location, time and date and sample`s name. Then, the bottle is placed in transport box and return it to the lab within 24 hours for in-situ analysis.

3.4.1 Instrument to Analyze Water Quality

The temperature of water sample is recorded by mercury thermometer with range 0-160 °C. pH and temperature parameters are measured with pH meter (model Hanna HI 2211) and Eutect Instrument pH 510. DO and BOD are measured by Dissolve Oxygen Meter. Method to determine BOD is using classical determination method that is BOD 5. Meanwhile, COD and NH_3-N are analyzed by Multipara Meter Lab-Photometer and HACH DRB 200.

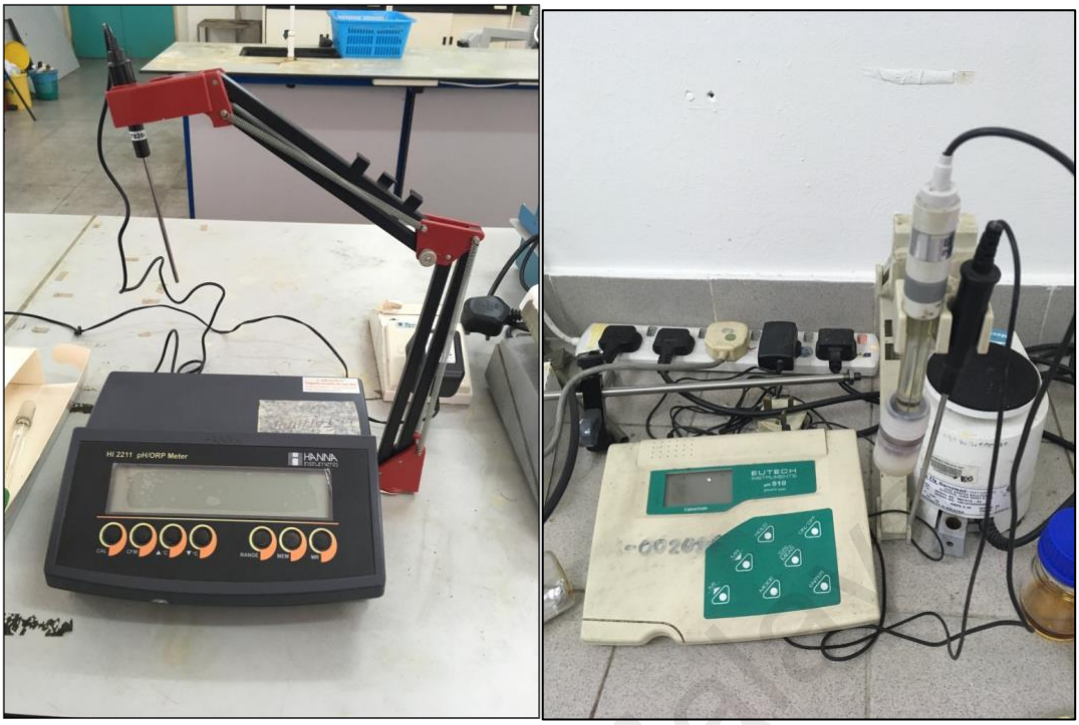

Figure 3.4.1(a) Left side of the picture is pH meter (model Hanna HI 2211) and the right side of the picture is Eutech Instrument pH510. Both instruments are used to detect pH and Temperature of the samples

Figure 3.4.1 (b) Dissolve Oxygen Meter to analyze Dissolve Oxygen and Biochemical Oxygen Demand

Figure 3.4.1(c) Left side of the picture is HACH DRB 200 and the right side of the picture is Multipara Meter Lab-Photometer. Both equipment is used to analyze COD and Multipara Meter Lab-Photometer to analyze Ammoniacal-Nitrogen

Figure 3.4.1(d) DR/890 colorimeter (HACH) to analyze TSS

3.5 Data collection by using Interview

The purpose of this interview is to figure respondent`s knowledge towards maintenance of RWHS and awareness on the system. In this study, one of the staff from UM Water Warriors was interviewed. In this thesis case study writing, one of the board members in the bank was interviewed. Semi-structured interview was directed and conversation was recorded by taking hand writing notes.

1. What is the existing method for maintenance RWHS tanks in UM?
2. How many times cleaning take place on each of the tank in a months or year?
3. Is there any activity in cleaning roof or the catchment surface? If yes how many times in a months or year?
4. Is there any inspection activity on the RWHS tanks?
5. Are there any activities involving students with RWHS?

3.6 Analyzing and Reporting

Data obtained will analysis by Microsoft Excel version 2019 to determine the association between variables. All data for physico-chemical parameters in this study are shown in the average.

CHAPTER 4: RESULTS

4.1 Condition of RWHS Tanks

Results is obtained from the field investigation and observation in each location. The results of the survey based on the condition of each tank which are include the usability of the tanks, functioning of pipe and water flow. From the finding, each of the location is marker with “blue tick” to represent the tank is good condition and working well and “Red X” to represent the tank is in poor condition and cannot be used. This finding reflects the awareness of the community of University of Malaya including management, employees and students in the importance of RWHS at their compound. The investigation was done further to propose and recommend on promoting use of collected rainwater in University Malaya Compound among students and UM community.

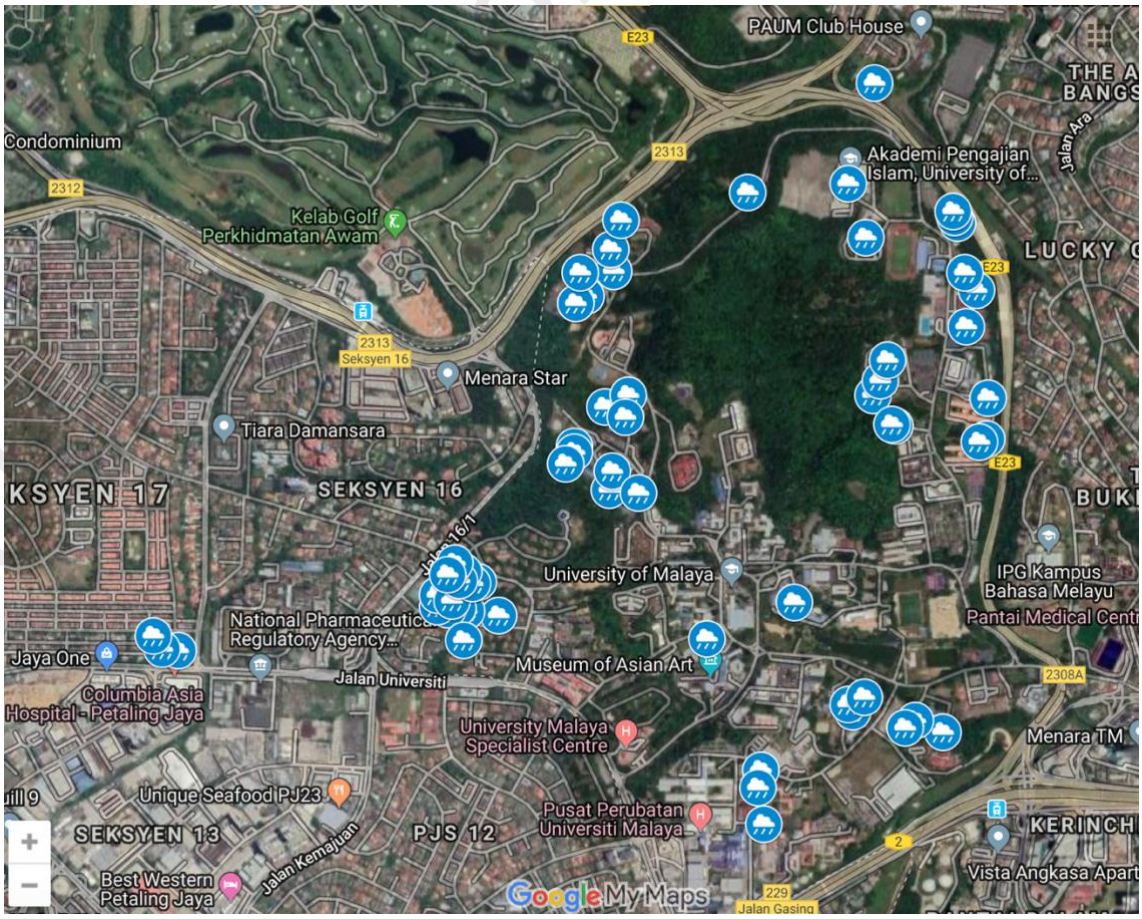

Figure 4.1 (a) Rainwater Harvesting system tank scattered around UM

A total of 63 tanks at 24 different location has been investigated. Earliest year the tank has been built in 2014 and ended in 2017. Most of the students` residential area has RWHS tanks for convenient and favorable need. In facts, to promote sustainability in the campus area. However, the facility may mostly be used by workers or contractors.

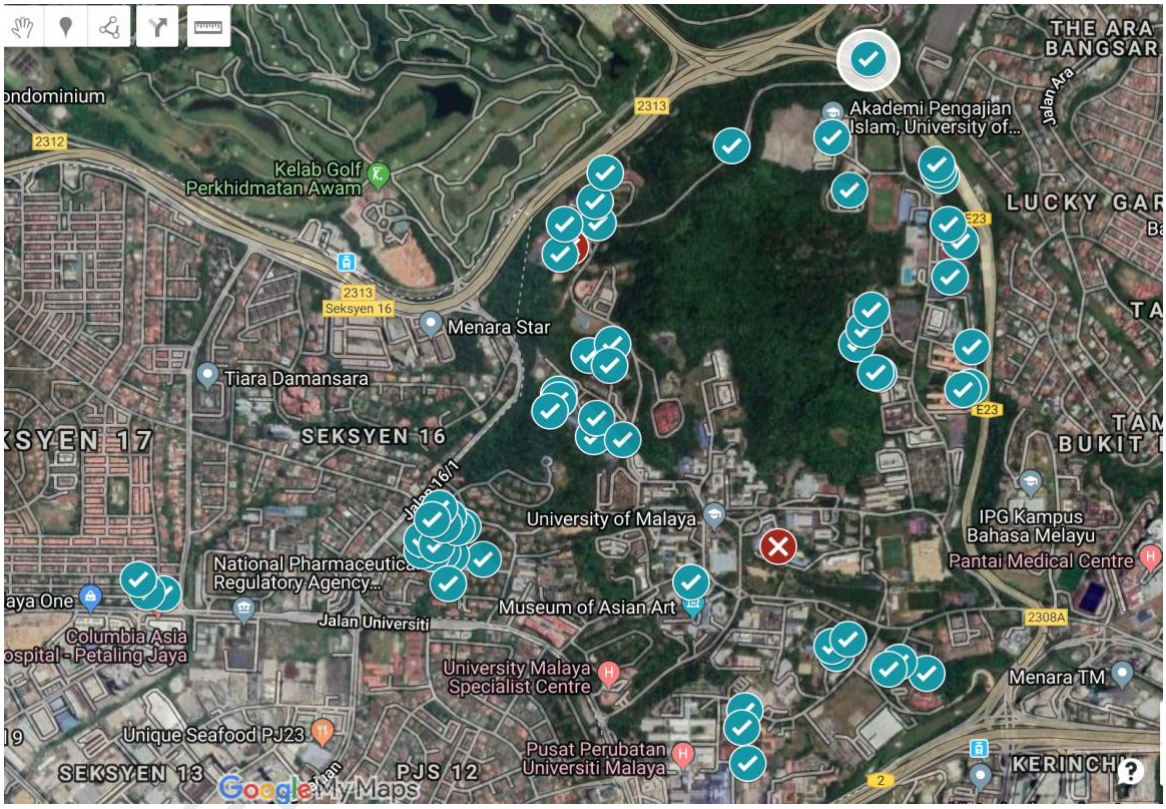

Figure 4.1 (b) Condition of the tanks where "blue tick" represent good condition whereas "red X" represent poor condition of the tank.

Table 4.1 Summary on the Condition of RWHS Tanks

Number of RWHS tanks	Condition of Tanks
61	Good: Good water flow, Pipes function well
2	Poor: Unusable RWHS tanks due to tanks not collecting rainwater, missing and

broken pipes (refer figure 4.1.2(a) and 4.1.2(b))

4.1.1 Good Condition of RWHS Tanks

Good condition of RWHS tanks is determined by observation on the tanks. The tanks are function well and can be used. The pipes or drain are not broken, and the water can flow at it maximum. Besides, there is no odour from the collected rainwater. Below is the information table for the RWHS tanks that are in good and excellent condition. Excellent RWHS tanks when the water flow is high and shows clear water with less sediments in it. For good condition, the rate of water flow is not high when the pipes are opened at maximum and there are some of the tanks, where the water is not clear and has sediment in it. However, maintenance is needed for the tanks to make sure it can be used for a long time. Below is the information of capacity and year built of RWHS tanks from UM Living Lab (Water Warriors) (2019) and good condition of tanks based on observation in field investigation.

Table 4.1.1 Description of tanks located in University Malaya

Name	**Condition**	**Capacity**	**Year Built**
Raja Dr. Nazrin Shah Residential College (KK12) Tank B	Excellent	400 gallons	2014
Raja Dr. Nazrin Shah Residential	Excellent	400 gallons	2014

College (KK12) Tank A			
Raja Dr. Nazrin Shah Residential College (KK12) Tank C	Excellent	400 gallons	2014
Bus Depot (Tank A)	Good	400 gallons	2014
Bus Depot (Tank B)	Good	400 gallons	2014
Bus Depot (Tank C)	Good	400 gallons	2014
Zero Waste Campaign	Excellent	500 gallons	2016
Daya Sari Residential College (KK5) Tank A	Excellent	400 gallons	2014
Landscaping Nursery (Tank A)	Excellent	400 gallons	2014
Landscaping Nursery (Tank B)	Excellent	400 gallons	2014
Ungku Aziz Residential College (KK11) Tank A	Excellent	400 gallons	2014

Ungku Aziz Residential College (KK11) Tank B	Excellent	400 gallons	2014
Ungku Aziz Residential College (KK11) Tank C	Excellent	400 gallons	2014
Tun Ahmad Zaidi Residential College (KK10) Tank A	Excellent	400 gallons	2014
Tun Ahmad Zaidi Residential College (KK10) Tank B	Excellent	2,400 gallons	2014
Tun Ahmad Zaidi Residential College (KK10) Tank C	Good	5,468 gallons	2014
PALAPES Training Ground	Excellent	400 gallons	
Bangunan Azman Hashim	Excellent	400 gallons	2016

Kolej Kediaman Bestari (KK4) Tank A	Excellent	400 gallons	2014
Kolej Kediaman Bestari (KK4) Tank B	Excellent	400 gallons	2014
Kolej Kediaman Bestari (KK4) Tank C	Good	400 gallons	2014
Tuanku Kurshiah Residential College (KK3) Tank A	Good	400 gallons	2014
Tuanku Kurshiah Residential College (KK3) Tank B	Excellent	400 gallons	2014
Tuanku Kurshiah Residential College (KK3) Tank C	Good	400 gallons	2014
Cancer Farm	Excellent	400 gallons	2017
Tuanku Bahiyah Residential	Excellent	400 gallons	2014

College (KK2) Tank C			
Tuanku Bahiyah Residential College (KK2) Tank B	Excellent	400 gallons	2014
Tuanku Bahiyah Residential College (KK2) Tank A	Excellent	400 gallons	2014
Tunku Abdul Rahman Residential College (KK1) Tank A	Excellent	400 gallons	2014
Tunku Abdul Rahman Residential College (KK1) Tank B	Excellent	400 gallons	2014
Za'ba Residential College (KK7) Tank A	Excellent	400 gallons	2014
Za'ba Residential College (KK7) Tank B	Excellent	400 gallons	2014

Za'ba Residential College (KK7) Tank C	Excellent	400 gallons	2014
Kinabalu Residential College (KK8) Tank B	Excellent	400 gallons	2014
Kinabalu Residential College (KK8) Tank C	Good	400 gallons	2014
Ibnu Sina Residential College (KK6) Tank A	Excellent	400 gallons	2014
Ibnu Sina Residential College (KK6) Tank B	Excellent	600 gallons	2014
Ibnu Sina Residential College (KK6) Tank C	Excellent	400 gallons	2014
Tun Syed Zahiruddin Residential	Excellent	600 gallons	2015

College (KK9) Tank A			
Tun Syed Zahiruddin Residential College (KK9) Tank B	Excellent	600 gallons	2014
Tun Syed Zahiruddin Residential College (KK9) Tank C	Excellent	600 gallons	2015
Tun Syed Zahiruddin Residential College (KK9) Tank D	Excellent	600 gallons	2015
Tun Syed Zahiruddin Residential College (KK9) Tank E	Excellent	600 gallons	2015
Tun Syed Zahiruddin Residential	Excellent	600 gallons	2015

College (KK9)			
Tank F			
Tun Syed	Excellent	400	2015
Zahiruddin		gallons	
Residential			
College (KK9)			
Tank G			
Tun Syed	Excellent	400	2015
Zahiruddin		gallons	
Residential			
College (KK9)			
Tank H			
Tun Syed	Excellent	600	2014
Zahiruddin		gallons	
Residential			
College (KK9)			
Tank I			
Tun Syed	Good	600	2014
Zahiruddin		gallons	
Residential			
College (KK9)			
Tank J			
Tun Syed	Excellent	600	2015
Zahiruddin		gallons	
Residential			

College (KK9) Tank K			
Tun Syed Zahiruddin Residential College (KK9) Tank L	Good	600 gallons	2015
Tun Syed Zahiruddin Residential College (KK9) Tank M	Excellent	600 gallons	2015
Tun Syed Zahiruddin Residential College (KK9) Tank N	Excellent	600 gallons	2015
UM International House Tank A	Excellent	400 gallons	2014
UM International House Tank B	Excellent	400 gallons	2014
UM International House Tank C	Excellent	400 gallons	2014
Tadika UM (TADIKUM) Tank A	Good	200 gallons	2014

Daya Sari Residential College (KK5) Tank B	Excellent	400 gallons	2014
Daya Sari Residential College (KK5) Tank C	Excellent	400 gallons	2014
Tunku Abdul Rahman Residential College (KK1) Tank C	Excellent	400 gallons	2014
Rimba Ilmu	Excellent		2017
Academy Islamic Studies	Excellent	3000 L	2017

Figure 4.1.1(a) Good condition of pipe with clear water

Figure 4.1.1(b) RWHS tank located nearby Musolla at International House UM

Figure 4.1.1 (c) Worker use collected rainwater to clean to clean raw fish prior cooking at Zero Waste Campaign office

Figure 4.1.1(d) Good condition of RWHS tank

4.1.2 Poor condition of RWHS Tanks

From the observation during field investigation, there are two tanks at different location are unusable. There no water flowing out at Kompleks Perdana Siswa UM (KPS) tank A, only few drips. For Kinabalu Residential College tank A, it is completely unusable. Both tanks are not collecting water. There is a need for a prompt action to repair both tanks so it will have functionality.

Table 4.1.2 Descriptions of tanks located in University Malaya

Name	**Condition**	**Capacity**	**Year Built**	**Location**
Kompleks Perdana Siswa UM (KPS) Tank A	Unusable	93 gallons	2014	Kompleks Perdana Siswa UM (KPS) Tank A
Kinabalu Residential College (KK8) Tank A	Unusable, missing pipe	400 gallons	2014	Dining Hall

Figure 4.1.2(a) Pipe malfunction at Kompleks Perdana Siswa

Figure 4.1.2 (b) Missing pipe and unusable tank at Kinabalu Residential College

4.2 Results on Water Quality

The graphs presented are the average value for each of the water quality parameters for three times sampling in five different tanks and each are located in different areas throughout University Malaya campus. For reading pH, DO and temperature, the readings are taken after returned to the laboratory within 24 hours (Zreig, Ababneh, & Abdullah, 2019).

4.2.1 pH Parameter

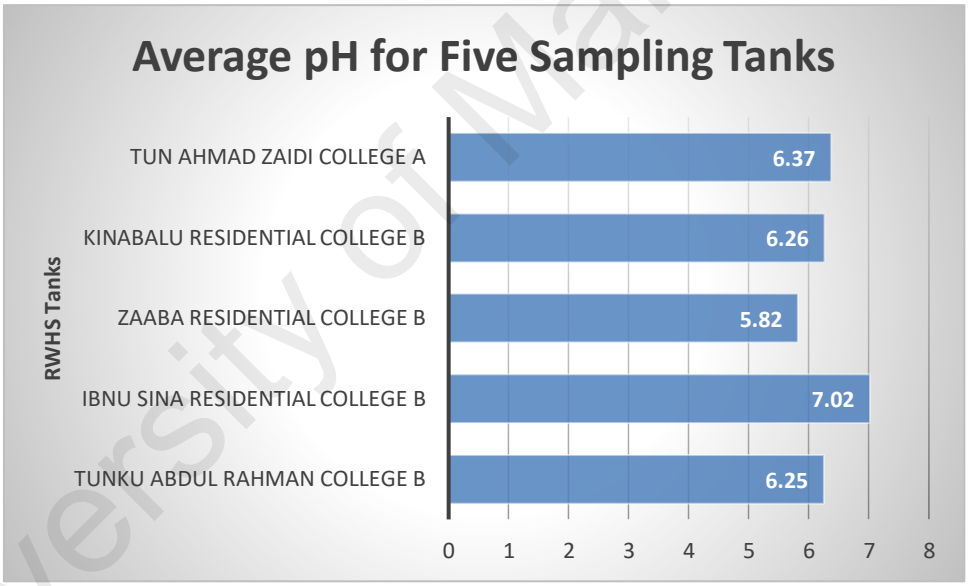

Figure 4.2.1 Average pH in five different tanks

Figure above shows average of pH reading for three times sampling. The average reading for the RWHS tanks is between 5.82 and 7.02. The highest average pH shown in the graph is 7.02 for Ibnu Sina Residential College tank B and lowest average pH value is 5.82 for Zaaba Residential College tank B. All the data approached to value neutral 7 and it is in between range of standard value stated by Ministry of Health Malaysia (MOH) that is between 5.5-9. Therefore,

the collected rainwater is safe and harmless, thus can be used for domestic purposes (Asman et al., 2017).

4.2.2 Temperature Parameter

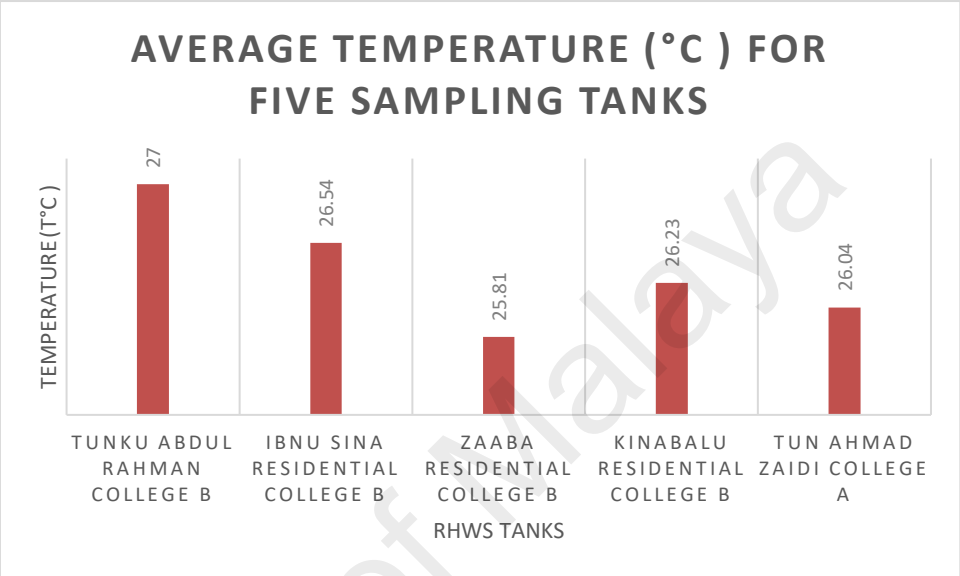

Figure 4.2.2 Average temperature in five different tanks

Figure above show average of temperature for three times sampling of five chosen tanks. The average temperature is between 25.80 °C and 27 °C. There is no significant different between each of the tank. The highest temperature recorded is 27 °C for Tunku Abdul Rahman College tank B and lowest temperature is 25.81 °C for Zaaba Residential College tank B.

4.2.3 Total Suspended Solid Parameter

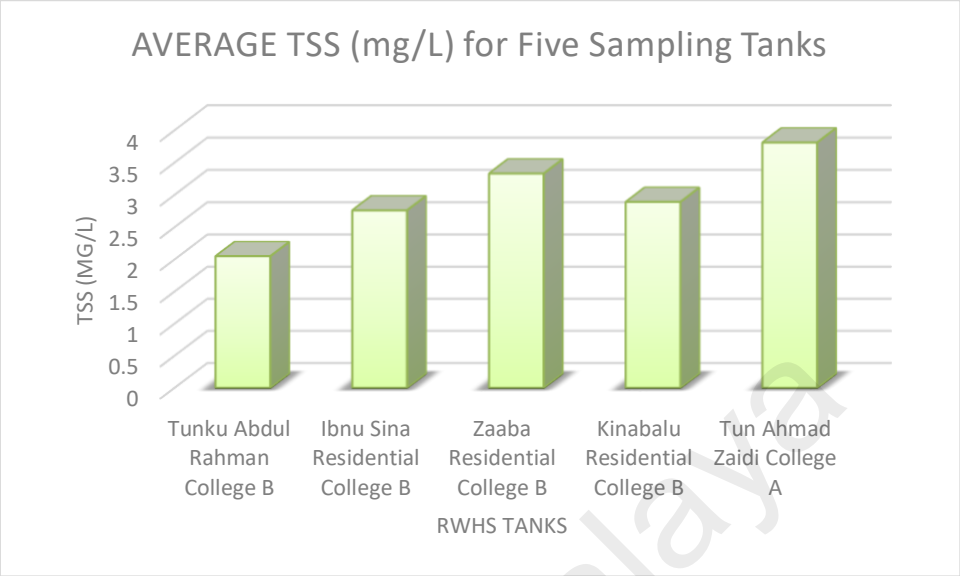

Figure 4.2.3 Average Total Suspended Solid for five different tanks

Figure above shows average of Total Suspended Solid for each tank. The lowest TSS value is 2.05 mg/L for Tunku Abdul Rahman tank B and the highest value is 3.81 mg/L for Tun Ahmad Zaidi Tank A. All the readings are in class I that is below 25 mg/L according to the NWQS Malaysia.

4.2.4 Dissolve Oxygen Parameter

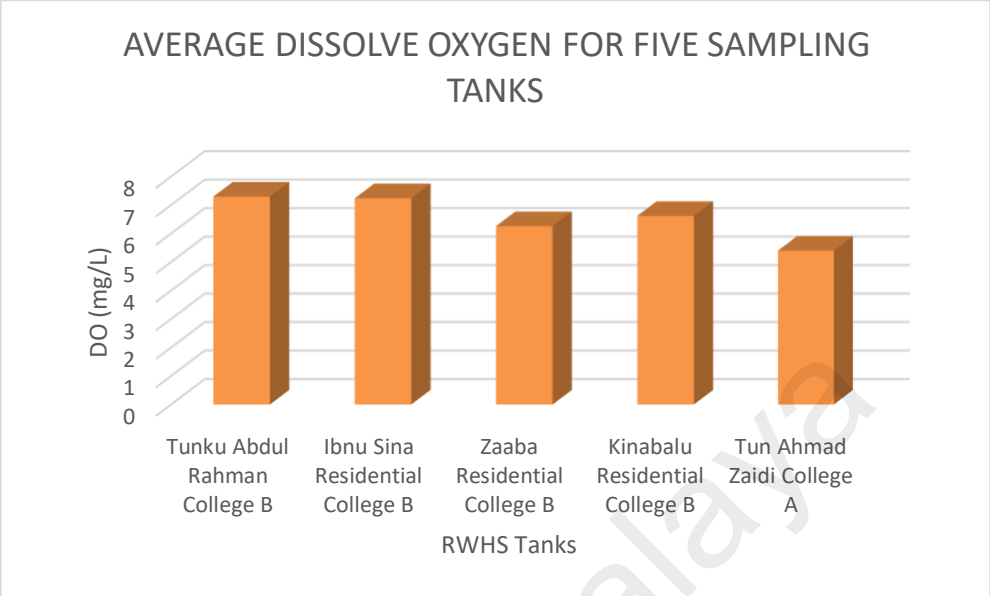

Figure 4.2.4 Average Dissolve Oxygen for five different tanks

Figure above shows the average Dissolve Oxygen concentration for each sampling point. Tunku Abdul Rahman College Tank B has the highest value of DO that is 7.3 mg/L and Tuan Ahmad Zaidi College Tank A has the lowest value of DO that is 5.4 mg/L. According to the NWQS Malaysia, College Tunku Abdul Rahman Tank B and Ibnu Sina Residential College Tank B is in class I and the rest of the three tanks, which are Zaaba Residential College tank B, Kinabalu Residential College Tank B and Run Ahmad Zaidi Tank A are class II.

4.2.5 Biochemical Oxygen Demand Parameter

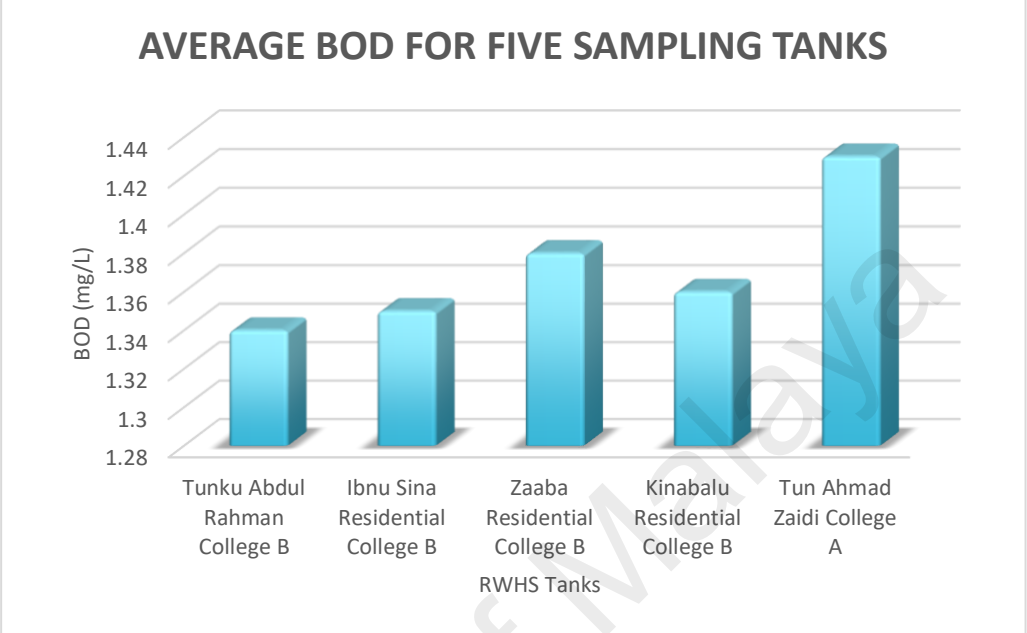

Figure 4.2.5 Average Biochemical Oxygen Demand for five different tanks

Figure above shows average value of Biological Oxygen Demand concentration for all five sampling points. Sample point from Tun Ahmad Zaidi College Tank A has the highest average value of BOD, 1.43 mg/L. The lowest value of BOD is sample rainwater tank from Tunku Abdul Rahman Residential College, 1.34 mg/L. Range of standard value for BOD by Ministry of Health Malaysia (MOH) is below 6 mg/L (Asman et al., 2017). All the samples are in class I.

4.2.6 Chemical Oxygen Demand Parameter

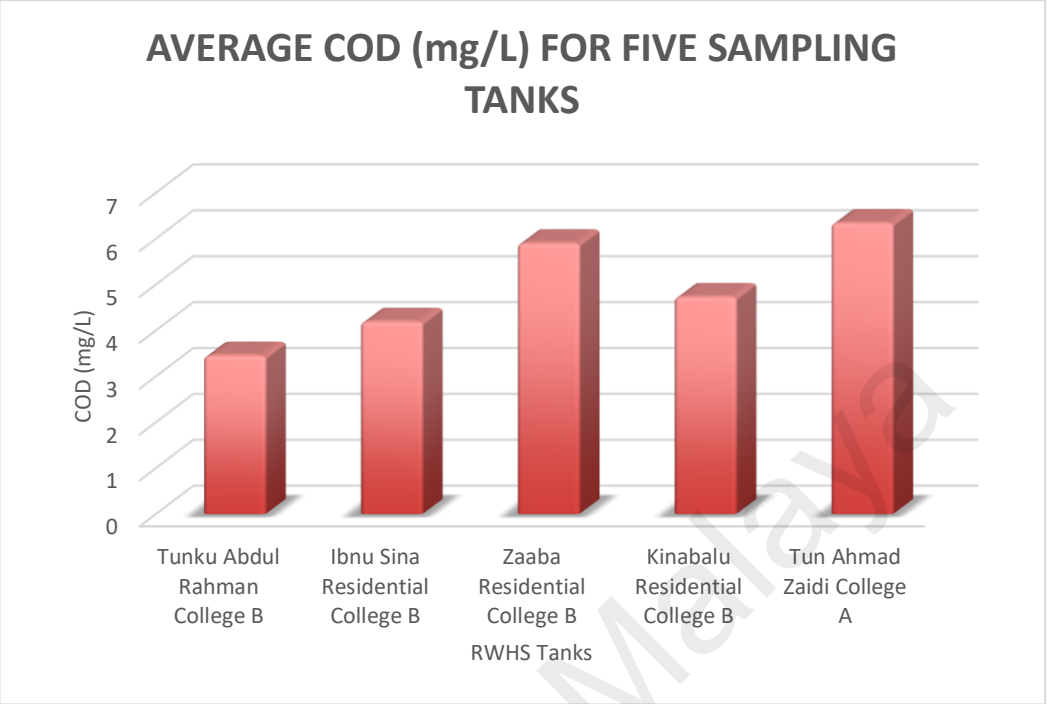

Figure 4.2.6 Average Chemical Oxygen Demand for five different tanks

Figure above shows average value of Chemical Oxygen Demand of five sampling points. The lowest value of COD is 3.45 mg/L from sample point Tunku Abdul Rahman College Tank B and highest average value of COD is 6.34 mg/L from sample point Tun Ahmad Zaidi College Tank A. All the average value of COD for all five sample points is below 10 mg/L, maximum allowable range stated by Ministry of Health Malaysia (MOH). All the samples are in class I.

4.2.7 Ammoniacal Nitrogen Parameter

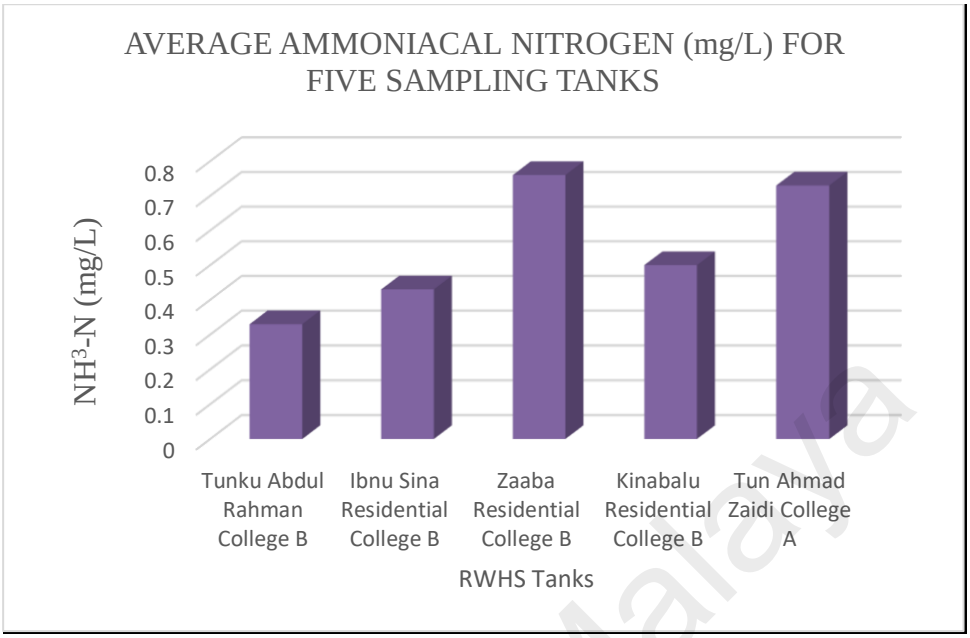

Figure 4.2.7 Average Ammoniacal Nitrogen for five different tanks

Figure above shows the results of the average value Ammoniacal Nitrogen for five sampling points. The highest value of NH_3-N is o.76 mg/L from sample RWHS tank Za`ba Residential College and lowest value is 0.33 from sample RWHS tank A Tunku Abdul Rahman college. All the sampling points is in class III according to the NWQS Malaysia except for sample point from Tunku Abdul Rahman College Tank B is in class IIB.

4.3 Results on the Interview

From the interview session with the UM Water Warrior staff, there is no maintenance have been done on the RWHS since in the early years it has been built. Besides, there is no cleaning process that has been taken place including cleaning the roof and storage tank. Inspection may have not been done on the RWHS tanks; therefore, it could be a reason why there are unusable RWHS

tanks. On the other hand, there are lack of activity engaging students with the RWHS, hence this may show their lack of awareness on the importance of the system not just in UM but on the environment. By having activity with RWHS, it may encourage students to use the facility actively.

4.4 Observation on RWHS during Field Investigation

From the field investigation and observation, the collected rainwater has been used for some activities such as cleaning, washing tools and watering plants, however it has not been used to its fullest extent. Some of the location of the tanks, especially tanks in residential college are situated in isolated area and hide from the view, where it is not the pathway of the students. For example, Tun Syed Zahiruddin Residential College tank J, Tun Ahmad Zaidi tank C and International House tank A.

Figure 4.4(a) Tank B from Tun Syed Zahiruddin Residential College situated in isolated area

Figure 4.4(b) Untidy area at tank C from Tun Syed Zahiruddin Residential College

On the other hand, there are suspended sediments in the water coming out from the pipe from a certain tank for example Kinabalu Residential College tank C, Tun Ahmad Zaidi Residential College tank C and Tun Syed Zahiruddin Residential College tank J. The rainwater tanks are not an active tank and there is lack of consumption on the collected rainwater. Most of the RWHS tanks are not actively used by students, except for workers and contractors for maintenance works, therefore information on water quality shall be present on the tanks and cleanliness may encourage students to use the facility.

CHAPTER 5: DISCUSSION

5.1 Analysis on the Condition of RWHS tanks

Finding shows that a total of 61 tanks are in good condition and 2 tanks located in Kompleks Perdana Siswa and Kinabalu Residential College (tank A) are in poor condition. RWHS Tank at Kompleks Perdana Siswa is unusable as the tank not collecting rainwater, hence the pipe is broken. For RWHS tank A Kinabalu Residential College, the tank has been abandoned and the pipe is missing. However, good condition tank for example, tank C Kinabalu Residential College and tank J Tun Syed Zahiruddin Residential College, the water flow with impurities at the beginning when the pipe is opened, and it took some time to show clear water. This may be due to lack of use among students as the location of the tank are in isolated area. According to Wurthmann (2019), one of the possible contaminants in the harvested rainwater include suspended sediments.

RWHS tanks located in Raja Dr. Nazrin Shah Residential college are located in strategic area as tank A nearby to the motorcycle parking area, therefore it is not difficult for the students to wash their vehicles and tank B and C nearby to the cafeteria. From the investigation, the collected rainwater has been used for cleaning purposes for example washing dirty tools and shoes and cleaning floors.

Ibnu Sina Residential College (KK6) Tank C, Ungku Aziz Residential College (KK11) Tank A and UM International House Tank A located nearby musolla and surau for ablution activity and worker at Zero Waste Campaign office use

collected rainwater for cooking. RWHS tank at PALAPES training ground has been used for toilet flushing. Literature from Zreig, Ababneh, & Abdullah (2019) stated that previous study from Nanyang Technological University, Singapore rainwater collected that has been used for toilet flushing able to cover 12.4% from monthly water bill and large amount of rainwater has been collected to cover Tokyo, Fukouka and Nagoya for watering plant and toilet flushing.

5.2 Water Quality Analysis

Previous study stated that pH 5.71 can be use for washing and showering (Asman et al., 2017). According to Kasmin et al (2016), World Health Organization (WHO) and the U. S. Safe Drinking Water act standardized the allowable ranges of PH for drinking water to be from 6.5 - 8.5. Previous study shows that the average pH for rainwater is between 5.8 and 8 (Zreig, Ababneh, & Abdullah, 2019; Asman et al., 2017). On the other hand, the normal range of water in Malaysia is 24 ° C to 31 ° C (Asman et al., 2017). The temperature of sample rainwater in normal temperature as follow by the weather from surrounding.

TSS is caused by the inclusion of external factors carried by the flowing water that can help increase the parameter concentration (Asman et al., 2017; Nosrati, 2017). Sample point from Tun Ahmad Zaidi College Tank A situated nearby trees. TSS is mainly due to particles or pollutants found on the roofs of buildings such as dust, dust, dried leaves or bird dung were brought together by the rainwater that entered the catchment area (Zreig, Ababneh, & Abdullah, 2019; Nosrati, 2017). The rooftop and storage tank must be clean regularly to

ensure the water quality parameters is not deteriorating. Clean catchment area and storage tank keep the collected water is suitable for domestic use (Zreig, Ababneh, & Abdullah, 2019). According to Asman et al (2017), DO is inversely proportional to the TSS concentration, therefore DO reading value at the sampling point affected by TSS concentration. This is due to TSS oxidation using oxygen. Therefore, there is moderate correlation between DO and TSS concentration.

Higher amount of BOD is due to the tank contain higher organic compound that a microorganism can decompose, and this process requires dissolved oxygen. Therefore, microbe then will enter storage area to decompose organic matter (Asman et al., 2017). Microbial pathogens from the rainwater in the building`s roof obtained from the feces of birds, rodents or other animals making the building a nest (Zreig, Ababneh, & Abdullah, 2019; Wurthmann, 2019). Previous study suggested that rainwater from the catchment area could be contaminated and risk to health (Zreig, Ababneh, & Abdullah, 2019; Gwenzi et al., 2015).

COD value is high when more oxygen is used to facilitate in the oxidation process of chemical pollutants and various chemically oxidized organic substances. According to Asman et al (2017), TSS comprises components both organic and inorganic matter. For oxidation processes, organic compounds in water use oxygen. High levels of TSS are therefore associated with high levels of COD. Average value of TSS for sample from Tun Ahmad Zaidi College tank A has the highest value of TSS.

Combustion of fossil fuels, traffic exhaust and industrial activity contribute to the amount of NH_3-N in rainwater (Gwenzi et al., 2015). University Malaya located in the middle of Kuala Lumpur; rainwater may be exposed to such pollutants. Contamination to the rainfall exists from the source to the consumer point (Zreig, Ababneh, & Abdullah, 2019), therefore it may be difficult to maintain its safety for people use for domestic purposes. However, harmlessness to the consumer can be achieve through the regular maintenance and management of RWHS. According to the study, factor of deteriorating water quality are level of maintenance and storage time.

5.3 Control Measures for sustainable System

Based on the interview session with the water warrior personnel regarding on maintenance of RWHS, Control measures are developed for future reference to maintain campus sustainability program.

Stakeholders are one of the important elements in keeping the project or program to be successful. In this case, stakeholder management have the responsibilities in keeping the recycle water system is perform and safe to be use. Stakeholders close involvement can keep the sustainability of water supply system in UM. Therefore, investment in maintenance work to the RWHS shall be apply, in facts, for future plan the system shall be improve, for example put a filter in the harvested rainwater tank so the water can be potable. Hence, embarking a sustainable and green campus.

The harvested rainwater quality is crucial to be monitored once in a while. It is not just for safety and health purposes, also to gain trust among consumers to use the water with confidence. Therefore, water quality monitoring shall be done once in every 6 months and recorded. Engaging students with the activity help in creating sense of responsibilities to maintain sustainability in UM campus and better environment. Encouragement from the management in university and investors may necessary to make it work. For example, tender project regarding water analysis in RWHS tanks in UM.

Cleaning the roof or catchment area is necessary as most of the tanks are not with filter except for tanks in Academic Islamic Studies. The cleaning shall be done once in a year, or twice if possible. Development and maintenance department in university have the responsibilities in keeping the roof is clean so the water quality in RWHS tanks are excellent. Since there are a lot of RWHS tanks scattered in UM, each of residential college may participate in cleaning for college activity purposes.

Maintenance on the system include cleaning gutters, storage tank and filtration for tanks in Academic Islamic studies must be done at least twice in a year and recorded. Some of the parts may need to be replace and improve after some time. The person-in-charge must be done by maintenance person from Jabatan Pembanggunan & Penyelengggaraan Harta Benda (JPPHB).

Inspection is one of the important activities to be done in maintaining sustainability of RWHS in UM. Inspection shall be done on schedule and every damage must be recorded. Regular inspection for each of the tanks must be done at least twice a year. Inspection shall be done by the person who are

responsible for the task, which may be from maintenance person from maintenance and development department in university or from the committee members of the RWHS project.

5.4 Recommendation to Develop an Awareness in UM communities on RWHS

Based on the observation during field investigation, it is necessary to involves UM community with the RWHS program to create an awareness in importance of the RWHS system that not just in UM campus but in Malaysia. Recommendation are developed as an initiation to creating consciousness to use recycle rainwater in the campus.

Keeping harvested rainwater tank clean is important to secure safety for its consumer and confidence for them to use the water for any purposes willingly. According to Nosrati (2017) & Gwenzi et al (2015), the roof rainwater may contain pollutants and contaminants. Therefore, the roof has to be clean from dust, dried leaves and other contaminants where it is primary surface for rainwater collection. The gutters also need to clean from dust, bird poop and other organic matter especially when there is no rain for long period of time. Overhanging branches from the trees shall be cut to prevent dried leaves enter the catchment area. Therefore, schedule on the management and maintenance on the harvested rainwater tanks shall be continuous and dutifully follow. Commitment and investment from stakeholders are necessary to make it operationalize.

Studied from United Nation has stated water scarcity is increasing therefore we may have to depend on recycle water in the future. Setting up water filtration system in RWHS tanks may necessary to reduce value of COD in the collected rainwater due to acid rain in the city, thus increasing water quality. It is also a cost-effective as UM communities can use the recycle water as a tap water. The water may not just use for washing floors and irrigation, but it also can use to wash clothes and shower. On the other hand, installing the RWHS for flushing toilets can reduce tap water usage. By relying on their own source of water, use of tap water can be reduce tremendously. Supports from stakeholders are very important to make it work.

Cleaning program in residential college to clean the harvested rainwater tank area could be done by students and communities. Working hand by hand among UM communities is significant in maintaining campus sustainability. On the other hand, Signage shall be place nearby the harvested rainwater with gentle reminder for the students to make use of the facility and save water. Keeping the area clean is also important, so people can use the facility with pleasant and comfortability.

Artwork such as murals is one of the powerful communication tools that help to promote peoples` way of thinking and deliver awareness messages towards unity. The messages could be anything relate to the environment. For example, by doing an artwork on RWHS tanks, this can attract students and UM community to use the recycle water. From the artwork, we can promote sustainability and improving the university image. There are several places that have incredible arts and becoming one of the attraction places. For example,

fire extinguisher with mural arts in Jakarta Airport, mural on water tank in New Mexico and mural on electric meter in Long Beach, California. Support in finance from the stakeholders are important to implement the project in UM. Example on the artworks that could be done on RWHS tanks in UM are present (Kasmin, Bakar, & Zubir, 2015)in appendix.

Figure 5.4(a) Mural art with fire extinguisher in Jakarta Airport

Figure 5.4(b) Mural on water tank in Las Cruces, New Mexico

Figure 5.4(c) Mural on electric meter by Tom Bob in Long Beach, California

CHAPTER 6: CONCLUSION

6.1 Introduction

Analysis of water quality on RWHS is investigated in this study. During field investigation and observation on each of RWHS tanks, the condition of each tanks and location of the tanks is observed. Interview is done to investigate the maintenance method and schedule of RWHS in UM. From the interview, control measures are developed to ensure RWHS sustainability and from the observation during field investigation, recommendations are developed to increase an awareness among students and communities in UM.

6.2 Conclusion

The results highlighted from 63 RWHS tanks, only two of the tanks is in poor condition, which are Kompleks Perdana Siswa UM (KPS) Tank A and Kinabalu Residential College Tank A.

From water quality analysis, all the water quality parameters are between class I and III by NWQS. The average pH reading for the RWHS tanks is between 5.82 and 7.02 and based on NWQS, all the tanks are in class I. The average temperature of RWHS tanks is between 25.80 °C and 27 °C. There is no significant different between each of the tank.

The lowest TSS value is 2.05 mg/L for Tunku Abdul Rahman tank B and the highest value is 3.81 mg/L for Tun Ahmad Zaidi Tank A. All the tanks is in class I. Tunku Abdul Rahman College Tank B has the highest value of DO that is 7.3 mg/L and Tun Ahmad Zaidi College Tank A has the lowest value of DO that is 5.4 mg/L. According to the NWQS, College Tunku Abdul

Rahman Tank B and Ibnu Sina Residential College Tank B is in class I and the rest of the three tanks, which are Zaaba Residential College tank B, Kinabalu Residential College Tank B and Run Ahmad Zaidi Tank A are in class II. Sample from Tun Ahmad Zaidi College Tank A has the highest average value of BOD, 1.43 mg/L. The lowest value of BOD is sample rainwater tank from Tunku Abdul Rahman Residential College, 1.34 mg/L. All the samples are in class I.

The lowest value of COD is 3.45 mg/L from sample Tunku Abdul Rahman College Tank B and highest average value of COD is 6.34 mg/L from sample point Tun Ahmad Zaidi College Tank A. All the samples are in class I.

The highest value of NH_3-N is O.76 mg/L from sample Za`ba Residential College RWHS tank B and lowest value is 0.33 from sample Tunku Abdul Rahman Residential college RWHS tank A. All the samples in class III according to the NWQS Malaysia except sample from Tunku Abdul Rahman College Tank B is in class IIB.

6.3 Recommendation for Further Work

This study provides an information on condition RWHS tanks in UM and water quality on certain RWHS tanks. Therefore, for future study is it recommended that a full analysis on water quality in all RWHS with deeper analysis should be taken place. Below is the significance of the findings of this study:

1. Provide information in condition of RWHS tanks scattered in University Malaya

2. Provide and determine level of water quality parameters in collection of harvested rainwater.
3. Provide ideas and partial solutions for control measure to maintain sustainability of RWHS in University Malaya.
4. Provide ideas and recommendation in creating awareness among UM communities based on observation from field investigation.

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