# THE EFFECT OF TRANSMEMBRANE PRESSURE (TMP) TOWARDS THE HARVESTED RAINWATER QUALITY

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# ABSTRACT

This thesis discussed about the effect of pressure on the membrane surface towards the quality of harvested rainwater using rainwater harvesting system. The objectives for this research are to determine the characteristics of harvested rainwater and treated water taken from the rainwater harvesting system in Universiti Malaysia Pahang. By testing some parameters which are pH, conductivity, turbidity, colour, total coliform and E.coli, the quality of the water samples taken at the system will be checked whether it is complied with the standard of drinking water which is National Standard of Drinking Water Quality. This thesis also describes the comparison of the characteristics of treated water quality in terms of pressure variation using membrane filtration in Laboratory and Gallery based on several parameters according to the Malaysian National Drinking Water Quality Standards. From the results, the quality of treated water using rainwater harvesting system is believed to become one of the sources of drinking water for people's usage. Other than that, by using the pressure driven membrane processes as the physical treatment for the water treatment, the quality of the treated water can be improvise. By using high pressure on the membrane, the quality of water increase since the contaminants that have been removed by the membrane is higher than using the low pressure since the flux of the water is high. As the results is obtained, it can be concluded that rainwater harvesting system is the water treatment that can be applied on many places even at home and by adding the physical treatment to the system such as membrane filtration, the quality of water produced can be more healthier for the users.

# ABSTRAK

Tesis ini membincangkan tentang kesan tekanan pada permukaan membran terhadap kualiti air hujan dituai menggunakan sistem penuaian air hujan. Objektif kajian ini adalah untuk menentukan ciri-ciri dituai air hujan dan air bersih yang diambil dari sistem penuaian air hujan di Universiti Malaysia Pahang. Dengan ujian beberapa parameter seperti pH, konduktiviti, kekeruhan, warna, jumlah koliform dan E.coli, kualiti sampel air yang diambil pada sistem akan diperiksa sama ada ia mematuhi piawaian air minuman yang ditetapkan oleh Piawaian Kualiti Air Minuman Kebangsaan Malaysia. Tesis ini juga menerangkan perbandingan ciri-ciri kualiti air yang dirawat dari segi perubahan tekanan menggunakan penapisan membran di Makmal dan Galeri berdasarkan beberapa parameter mengikut Piawaian Kualiti Air Minuman Kebangsaan Malaysia. Daripada keputusan, kualiti air yang dirawat menggunakan sistem penuaian air hujan dipercayai menjadi salah satu daripada sumber-sumber air minuman untuk kegunaan rakyat. Selain daripada itu, dengan menggunakan tekanan proses membran sebagai rawatan fizikal untuk rawatan air, kualiti air yang dirawat boleh meningkat. Dengan menggunakan tekanan tinggi pada membran, kualiti air lebih bagus disebabkan bahan-bahan yang telah dikeluarkan oleh membran adalah lebih tinggi daripada menggunakan tekanan rendah. Dari keputusan yang diperolehi, kesimpulan yang dapat dibuat ialah sistem penuaian air hujan adalah rawatan air yang boleh digunakan pada banyak tempat walaupun di rumah dengan menambah rawatan fizikal pada sistem sebagai contoh, penapisan membran, kualiti air yang dihasilkan boleh menjadi lebih sihat untuk pengguna.

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| | |
|---|---|
| SWM | Southwest Monsoon |
| NEM | Northeast Monsoon |
| RWH | Rainwater harvesting system |
| CSOs | Combined sewer overflows |
| MF | Microfiltration |
| UF | Ultrafiltration |
| NF | Nanofiltration |
| DOM | Dissolved organic matters |
| WHO | World Health Organization |
| JMP | Joint Monitoring Programme |
| UMP | Universiti Malaysia Pahang |
| MWCO | Molecular weight cutoff |
| NOM | Natural organic matter |
| DBP | Disinfectant by products |
| EPA | Environmental Protection Agency |
| NTU | Nephelometric Turbidity Units |
| NaOH | Sodium hydroxide |
| $H_2SO_4$ | Sulphuric acid |
| UV | Ultraviolet |
| TCU | Total colour unit |

# CHAPTER 1

# INTRODUCTION

## 1.1 Introduction

Malaysia is a country that located near the equator which made Malaysia as the country that receives most rainfall every year. Climate in Malaysia is affected by the two monsoons in Malaysia which are the Southwest Monsoon (SWM) and Northeast Monsoon (NEM) which make the coast area in Peninsula Malaysia is tend to be exposed to the flood and extreme rainfall every year during NEM which happened from November until February.

Due to the unstable climate during these days and increasing numbers of population in Malaysia, the issues and problems have arisen and many prevention and steps of precaution has been taken towards these environmental issues. For an instance, the excessive amount of rainfall itself can leads to the most problematic issues such as flood and rain storms. Other than that, with the arising numbers of human, water resources has been limited since the fresh water in earth has been decreasing. So that, the methods to implement and solution to these problems of water has been introduced and proposed by the government in Malaysia to prevent the problems become worse.

Rainwater harvesting system (RWH) is one of the methods that can be implemented to cure this problem. It is one of the methods that have been introduced by

the government to play important roles to solve water need's problems and management practices towards water issues. The system are capable to make up the water sources, control the storm water and contribute in moderating combined sewer overflows (CSOs), reduce water withdrawals, lessen the energy use in order to reduce the greenhouse gas emissions (Gold et al., 2010).

This system also has been implemented to make the system become more efficient towards the quality of treated water for the purpose of drinking sources. Filtration should be done to remove any particles before it enters the tank. Pressure-driven membrane technology for microbial control is one of the methods that have been practiced for the treatment of water in drinking water supplies. Due to the existence of the microorganism in the water sources, membrane has been applied as the primary disinfection (Jacangelo and Watson, 2001). Membrane can be said as the excellent disinfection and because of the technology development, the cost of the membrane has decrease and made the usage of the membrane has been widen day by day.

Microfiltration (MF), ultrafiltration (UF), and nanofiltration (NF) are the membrane filtration process which applied on drinking water sources production and has been known over year (Zularisam et al., 2006). These filtration acts like a refining step for water treatment process (Metcalf and Eddy, 2003). Zularisam et al. (2007) claimed that MF and UF are designed to eliminate micro particles, which is the particles between 0.1 and 100μm in size and macromolecules, which is very large molecules. These involved inorganic particles, organic colloidal and dissolved organic matters (DOM). While UF is for eliminating the particulate matter, bacterial cells, and organic solutes from surface water (Zularisam et al., 2011).

## 1.2 Problem Statement

The decreasing amount of fresh water in Earth has awakened many researchers to implement many methods to overcome the problem. According to Briscoe (1995), there are more than a billion of human that have no access to fresh water and it is estimated that 1.7 billion humans have no sufficient hygienist. The pie chart below showed the lack of access of water in Earth according to WHO Joint Monitoring Programme (JMP) for Water Supply and Sanitation on 2012.

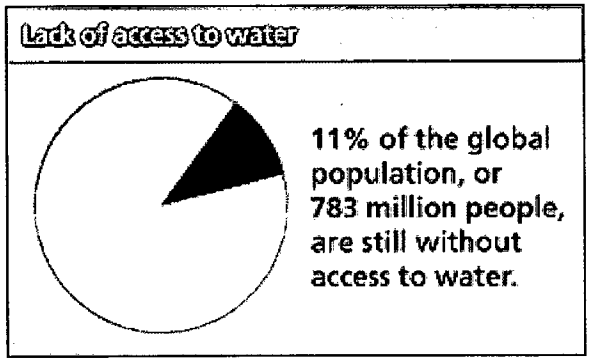


**Figure 1.1:** Pie chart of lack access of water in Earth

Source: WHO/UNICEF, 2012

Nowadays the amounts of fresh water in earth have only been used but not produce. In addition, with the increasing population, rapid urbanization and other environmental problem has brought large effect to the earth and made the fresh water issues become worse. This situation also leads to some consequences in the water demand and water supply in some countries.

## 1.3 Objective of Study

The main objectives for this research are:

(i) To determine the characteristics of harvested and treated rainwater using rainwater harvesting system according to the Malaysian National Drinking Water Quality Standards based on several parameters.

(ii) To compare the characteristics of treated water quality in terms of pressure variation using membrane filtration in Laboratory and Gallery based on several parameters according to the Malaysian National Drinking Water Quality Standards.

## 1.4 Scope of Study

The study is mainly focused on the rainwater harvesting system at Gallery in Universiti Malaysia Pahang (UMP). There are some samples have been taken at the rainwater harvesting system which has been installed at the highest floor of Gallery:

(i) Harvested rainwater

(ii) Treated rainwater

(iii) Rejection rainwater

(iv) Treated rainwater using pressure for 1 bar


**Figure 1.2:** Rainwater harvesting system at Gallery, UMP

These samples will be tested at the laboratory according to the National Standard of Drinking Water Quality based on the parameters which are:

(i) pH
(ii) Colour
(iii) E.coli
(iv) Turbidity
(v) Conductivity

Other than that, the collected rainwater at the Gallery will be tested in terms of changes in pressure at Laboratory to seek the characteristics of filtered rainwater. Then, the filtered rainwater using different pressure will be tested with the same parameters according to the Malaysian National Drinking Water Quality Standards.

## 1.5 Significant of Study

The significance of this study is to determine the quality of treated rainwater using rainwater harvesting system as a drinking source. The characteristics of the treated water will be based on the parameters stated in the Malaysian National Drinking Water Quality Standards. Other than that, this research is to determine the effect of pressure towards the quality of the treated water. By using the same parameters as the first objective, the characteristics of the treated water quality can be identified.

This research can contribute to establish the most efficient method to treat the rainwater for the purpose to increase the amount of fresh water with low cost. In addition, this research can overcome the water management issue that has become worse day by day.

## 1.6 Expected Outcomes

Through this research, the characteristics of harvested rainwater and treated water using rainwater harvesting system by testing several parameters can be determined. With the decreasing amount of fresh water in the Earth, these systems are believed can help those issues from become worse.

Other than that, the characteristics of the treated water quality in terms of pressure variation using membrane filtration in Laboratory and Gallery based on several parameters can be determined. With the advancement technology nowadays such as membrane filtration, the treated rainwater can improve the source of drinking water become more effective and healthier to the people.

# CHAPTER 2

# LITERATURE REVIEW

## 2.1 Introduction

The rainwater harvesting system (RWH) has been practiced for a long thousand years (Abdel Khaleq and Ahmed, 2007). By using simple techniques such as ponds and artificial reservoirs, those old system only act to be used for acquiring and keeping the rainwater which is from the rooftops, land surfaces or rock catchment (Helmreich and Horn, 2009). With the advancement of technology, these systems have been implemented days by days to get the effective results towards better environment and improvement of human's life.

According to Helmreich and Horn (2009), there are three major forms of rainwater harvesting system (RWH) which are in situ rainwater harvesting system, external water harvesting and domestic rainwater harvesting system. In situ rainwater harvesting system will gather the rainwater falls on the surface and will be store in the soil. While for external water harvesting system will collect the runoff which came from the rainwater over a surface on the other site and will be keep offside and the usage are for agriculture purpose. The domestic rainwater harvesting system will collect the rainwater from the roof, streets and courtyard runoffs.

## 2.2 Rainwater Harvesting System

Rainwater harvesting system is a system that has been implemented nationwide to overcome the water management issue nowadays. This system will collect rainwater from the rooftop and will be process before stored. Since rainwater is the direct source of water that can be access, this type of source has been managed and treated to make this source of water safe and beneficial for the users.

The water collected by these systems can be used for everyday usage such as washing, toilet flushing, gardening and cooling in household air conditioning systems. Other than that, it can be use to avoid overflow by storm water detention and retention by storage tanks, in ecological pools and reduce the charged on sewer pipes (Hyoungjun et al., 2012). Sometimes with the proper treatment, this system can provide water that can be claimed as source of drinking water.

## 2.3 Rainwater Harvesting System Basic Component

Rainwater harvesting system in UMP consists of several basic components which are collected rainwater tank, treated rainwater tank, membrane filtration, first flush and chlorine tank.

### 2.3.1 Rainwater Tank and Treated Water Tank

Figure 2.1 show that the collected rainwater tank at the left side while at the right side is the treated water tank. Collected rainwater tank is used to store the rainwater that was removed its contaminant using first flush diverter. For the treated water tank, the tank will stored the water that has been completely treated and can be use directly.

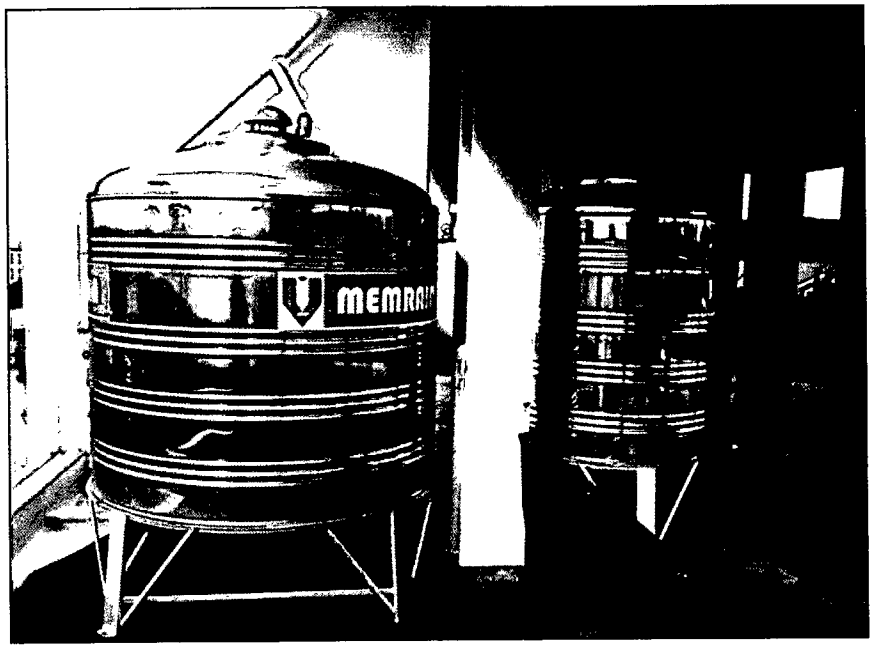

**Figure 2.1:** Collected rainwater tank and treated water tank

### 2.3.2 Membrane Filtration

Figure 2.2 shows the membrane filtration used in rainwater harvesting system in UMP. The membrane filtration is used in this system as a treatment tools to filter any smaller contaminant to enter the treated water (Jacangelo et al., 1995). Water that cannot pass through the membrane filtration is call rejection which is removed through the small pipe next to membrane filtration while the water that can pass through the membrane is called permeate. This membrane filtration used pressure driven mechanism to make sure the water filtered by these filtration become more effective in terms of microbial control in drinking water supplies.

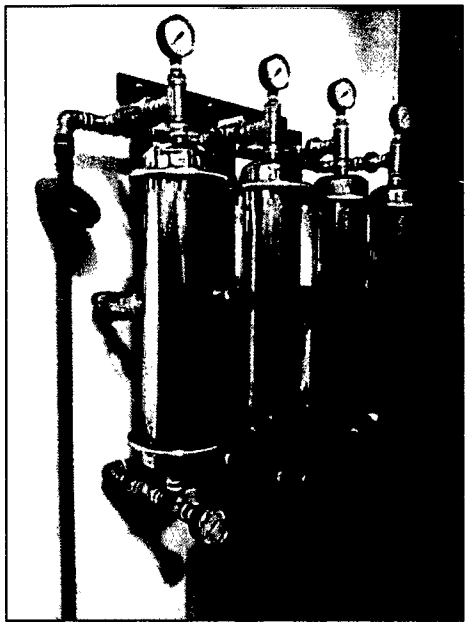

**Figure 2.2:** Membrane filtration

### 2.3.3 First Flush Diverter

In figure 2.3 shown the first flush diverter was used in rainwater harvesting system in UMP. Mechell (2009) said that the first flush component is used to be as a tool to remove any contaminant to enter the rainwater tank. Using this diverter can make the water quality become better, lessen the tank maintenance and protect the pump by preventing the contaminant from the roof from entering the tank.

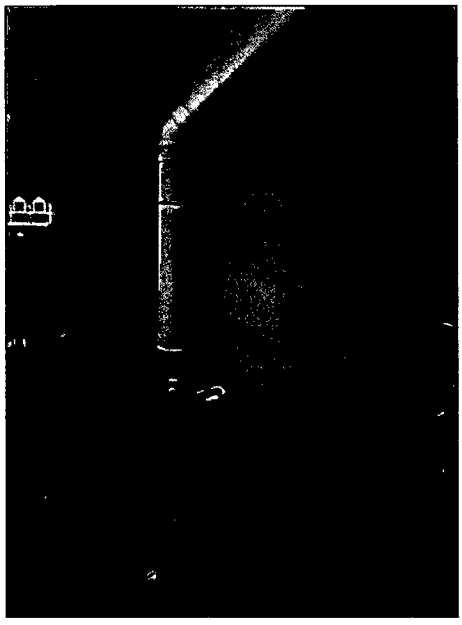

**Figure 2.3:** First flush diverter

### 2.3.4 Chlorine Tank

Figure 2.4 shown is chlorine tank used in this rainwater harvesting system which acts as a disinfectant for the treated water. By using chlorine, microorganism in the water will deactivate (Lingireddy and Thurvas, 2001).

**Figure 2.4:** Chlorine tank

## 2.4 Advantages of Rainwater Harvesting System

There are many benefits that can be obtained by installing rainwater harvesting system. According to Sarte (2010), rainwater harvesting system is believed to support water shortages in the region but however this situation is different based on the amount of rainfall in the region. Besides that, the cost of maintaining and upgrading water treatment plant will be reduce since the residents was not totally depends on water treatment plant as their primary sources. Rainwater harvesting system can reduces energy and greenhouse gas emissions during pumping, treating and distributing the water from the water treatment plant to the houses. Other than that, by set up the rainwater harvesting system, the water security will be increase since the residents has independent sources of water and this can help the country to minimize water losses during disruptive occurrence such as earthquake and energy blackout. With rainwater harvesting system installed in every house, people can managed to save money on their water bills and this has made rainwater harvesting system is more cost effective rather than water supply system. In addition, rainwater harvesting system can be reliable since it can improve the flood control in the country. This system will act as detention tanks and prevent the storm water to become out of control. Apart from that, the rainwater harvesting systems are dependable to increase surface water quality and reduces sewer overflow. The quality of surface water will increase since the pollutants have been wiped out during storm water will be harvest at the rainwater harvesting system first and this will prevent the high pollutant of water will be discharge to the river directly. By capturing rainwater, the overflow can be avoid, local water quality can be improve, the surges of sewer system can be reduce and also the energy use required for sewage treatment will be saved.

## 2.5 Disadvantages of Rainwater Harvesting System

Even though the rainwater harvesting system has a lot of advantages, there also might be some of disadvantages of this system. According to Worm and Hattum (2006), the main disadvantage of this system is due to the amount of rainfall itself. The rainfall distribution of each location is different and varies depends on the seasonal change and the location of the region. Aside from that, the investment cost might be high since the material use for this system is expensive. This system also has high maintenance and the operation of this system should be done properly. Regular inspection, repairing and cleaning should be done so that this system will work well. Other than that, the water quality produce by this system may be affected with air pollution, organic matter, bird droppings and other pollutants. Due to that problem, the physical treatment should be applied at this system to produce better water quality. This system is also sensitive towards the droughts season. The occurrence of long dry season and droughts will cause problem to the water supply produce by this system. In addition, the water supply of this system can be limited since the size of the catchment is smaller than water treatment plant.

## 2.6 Introduction to Membrane Filtration

Membrane can be defined as semi permeable materials which allow liquids or gas to pass through it. Membrane is capable to separate the contaminants from entering the products. Water will be pumped towards the membrane surface to make the product and waste become separated. Membrane filtration can be said as one of the methods that have been implemented to make sure the quality of water that has been treated is safe towards the human health and also to the environment.

Jacangelo et al., 1997 said that membrane can be described based on variable characteristics which are membrane pore size, membrane material and geometry, targeted materials to be removed, molecular weight cutoff (MWCO), type of water quality to be treated and treated water quality.

### 2.6.1 Forms of Membrane Filters

There are several forms available for membrane filters such as hollow fibre, spiral wound and ceramic. However the most common form of membrane that is used in water treatment is hollow membrane. Primarily in membrane filtration, hollow membranes are used for microfiltration and ultrafiltration. Figure 2.5 show the hollow membrane that is used for water treatment.

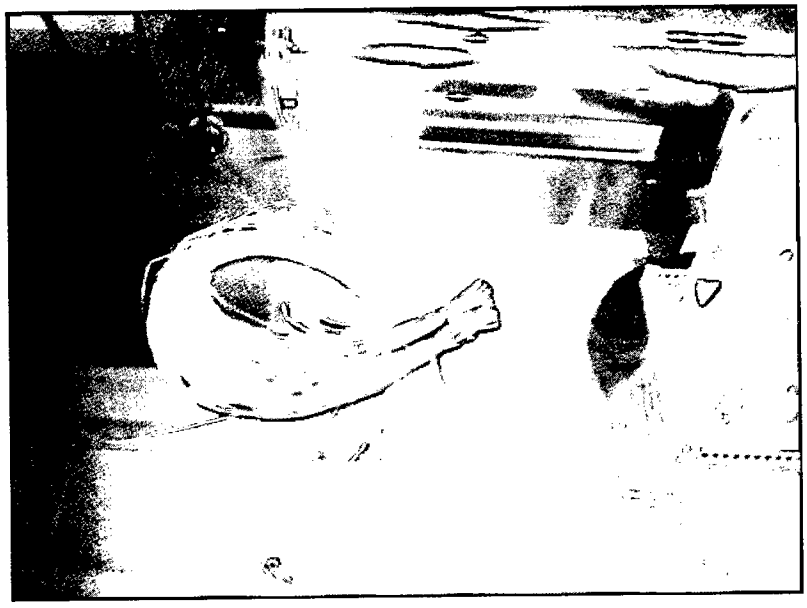

**Figure 2.5:** Hollow membrane