REMOVAL OF SOLIDS, TOTAL COLIFORM, E. COLI, UV254, COLOUR AND TURBIDITY USING ZEOLITE FILTER IN RIVERBANK FILTRATION

MUHAMMAD FIKRI BIN ABD WAHAB

SCHOOL OF CIVIL ENGINEERING
UNIVERSITI SAINS MALAYSIA
2017

REMOVAL OF SOLIDS, TOTAL COLIFORM, E. COLI, UV_{254}, COLOUR AND TURBIDITY USING ZEOLITE FILTER IN RIVERBANK FILTRATION

By

MUHAMMAD FIKRI BIN ABD WAHAB

This dissertation is submitted to

UNIVERSITI SAINS MALAYSIA

As partial fulfilment of requirement for the degree of

BACHELOR OF ENGINEERING (HONS.)
(CIVIL ENGINEERING)

School of Civil Engineering,
Universiti Sains Malaysia

June 2017

SCHOOL OF CIVIL ENGINEERING
ACADEMIC SESSION 2016/2017

FINAL YEAR PROJECT EAA492/6
DISSERTATION ENDORSEMENT FORM

Title:

Name of Student:

I hereby declare that all corrections and comments made by the supervisor(s)and examiner have been taken into consideration and rectified accordingly.

Signature: Approved by:

_______________________ _______________________

(Signature of Supervisor)

Date :

Name of Supervisor :

Date :

Approved by:

____

(Signature of Examiner)

Name of Examiner :

Date :

ACKNOWLEDGEMENT

In the name of Allah, the Most Gracious and the Most Merciful. Alhamdulillah, all praises to Allah for the strengths and His blessing in completing this project within the period given.

First and foremost, I would like to express my deepest gratitude to my final year project supervisor, Prof. Dr. Hamidi Abdul Aziz, for his support and guidance throughout the research. His continued support led me to the right way.

I am deeply thankful and offer my sincere gratitude to technical staffs of School of Civil Engineering USM who have always been helping me while running all equipment and supplies involved with my project.

I would also like to thank postgraduate students and who sacrificed their time to teach me the laboratory procedures that I did not understand and some techniques to handle certain equipment.

Finally, to my family and friends who have been helping and supporting physically and mentally, encouragement and financial support throughout all my studies here in Universiti Sains Malaysia Engineering Campus.

ABSTRAK

Pembangunan perindustrian yang pesat dan peningkatan di dalam urbanisasi sejak kebelakangan ini telah menyebabkan masalah pencemaran air yang teruk terutamanya kepada sumber bekalan air di Malaysia. Oleh kerana pencemaran yang amat teruk, sistem penapisan tebing sungai (RBF) yang menggunakan proses penapisan semulajadi mungkin boleh digunakan sebagai kaedah olahan awal yang lebih ekonomi. Walau bagaimanapun, keberkesanan rawatan RBF adalah bergantung kepada ciri - ciri fizikal air sungai dan jenis media penapis yang digunakan. Oleh itu, zeolite yang merupakan bahan penjerap mempunyai potensi untuk digunapakai dalam sistem RBF disebabkan oleh keupayaan pertukaran ion dan penyaringannya. Ciri-ciri fizikal dan kimia zeolite ditentukan terlebih dahulu dalam kajian ini dengan menggunakan kaedah Imbasan Elektron Mikroskop (SEM) dan Sinar-X Pembelauan (XRF). Seterusnya, zeolite ini diuji sebagai penapis dalam penyingkiran partikel, Jumlah Koliform, *E. Coli*, pepejal terlarut (TDS), pepejal terampai (SS), UV_{254}, warna dan kekeruhan. Saiz zeolite 1.18mm - 2mm telah digunakan sebagai media dalam ujian turus sebagai simulasi sistem RBF. Air daripada Sungai Kerian, Lubuk Buntar telah dianalisis terlebih dahulu sebelum kajian turus dijalankan. Berdasarkan keputusan SEM, zeolite yang digunakan terdiri dari gabungan kristal bersaiz mikron bersama liang-liang bersaiz kecil. Kehadiran partikel yang kurang daripada 0.5 µm didapati pada permukaan zeolite selepas penapisan. Seterusnya, keputusan XRF menunjukkan bahawa komponen utama zeolite adalah SiO_2 (79%) dan Al_2O_3 (13%) yang mewakili kumpulan *Clinoptilolite*. Hasil daripada kajian turus menunjukkan bahawa penyingkiran partikel dan jumlah pepejal terlarut (TDS) menggunakan zeolite tidak dapat ditentukan kerana kesan larut lesap zeolite ke dalam air. Di samping itu, pengurangan jumlah koliform dan *E. Coli* adalah hampir 100% penyingkiran dan tiada *breakthrough* berlaku sepanjang ujikaji.

Untuk pepejal terampai (SS) dan kekeruhan, proses penyingkiran mencapai 80% - 85% pengurangan dan juga tiada *breakthrough* berlaku sepanjang ujikaji. Walau bagaimanapun, penyingkiran UV_{254} dan warna mencapai nilai maksimum untuk tiga hari pertama penapisan sahaja dengan 60% - 73% untuk UV_{254} dan 75% - 87% penyingkiran untuk warna dan hampir mencapai *breakthrough* di akhir ujikaji. Zeolite yang beralkali juga telah menyebabkan peningkatan pH air yang telah diolah.

ABSTRACT

Massive industrial development in recent years, and an increase in urbanization have caused severe water pollution problem especially to water supply source in Malaysia. Since many water bodies in Malaysia are heavily polluted, riverbank filtration (RBF) which uses natural attenuation process could be a possible low cost pretreatment option. However, the effectiveness of the RBF treatment were depends on the physical characteristics of the river water and the type of filter media used. Therefore, zeolite which is an adsorbent has the potential to modify the RBF system due to its ion-exchange and straining capabilities. In this study, the physical and chemical characteristics of zeolite were first determined by using Scanning Electron Microscopy (SEM) and X-Ray Fluorescence (XRF) method. Next, the zeolite was tested as a filter to remove particles, total coliform, *E. Coli*, total dissolved solids (TDS), suspended solids (SS), UV_{254}, colour and turbidity. Zeolite with particle size 1.18 mm - 2 mm was used as porous media in the filter column as simulation to the RBF system. River water from Sungai Kerian, Lubok Buntar was characterized before conducted the column study. Based on the SEM results, the zeolite used were made from combination of micron-size crystal along with small size of pores. The presence of particles which less than 0.5 µm was found on the surface of zeolite after filtration. Next, the XRF results showed that the main components of the zeolite are SiO_2 (79%) and Al_2O_3 (13%) that represents its *Clinoptilolite* group. The results from the column study showed that the removal of particles and total dissolved solids (TDS) using zeolite were not able to be determined due to the leaching effects of zeolite into the water. Besides that, the removal of total coliform and *E. Coli* were almost 100% of removal and no breakthrough occurred throughout the experiment. For suspended solids (SS) and turbidity, the removal were 80% - 85% and also no breakthrough

occurred throughout the experiment. However, the removal of UV_{254} and colour achieved maximum value for the first three days of filtration with 60% - 73% for UV_{254} and 75% - 87% of removal for colour and almost achieved breakthrough at the end of experiment. Zeolite which is alkaline had also caused the increase of pH of the treated water.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

ASTM	American Society for Testing and Materials
CEC	Cation Exchange Capacity
COD	Chemical Oxygen Demand
DO	Dissolved Oxygen
DOC	Dissolved Organic Carbon
EBCT	Empty Bed Contact Time
EPA	Environmental Protection Agency
HLR	Hydraulic Loading Rate
NCPH	North Carolina Public Health
NWQS	National Water Quality Standards
NYSDH	New York State Department of Health
RBF	River Bank Filtration
SAC	Spectral Absorption Coefficient
SEM	Scanning Electron Microscopy
SMEWW	Standard Methods for the Examinations of Water and Wastewater
SS	Suspended Solids
SSWM	Sustainable Sanitation and Water management
TDS	Total Dissolved Solids
USEPA	United States Environmental Protection Agency
XRF	X - Ray Fluorescence

NOMENCLATURES

A	Cross sectional area
A_{eff}	Effective cross sectional area
D	Diameter
ε	Empty volume percentage
h	Adsorbent height
Q	Flow rate
V	Adsorbent volume
$V\varepsilon$	Empty volume
Vw	Volume of water

CHAPTER 1

INTRODUCTION

1.1 Background

There are many river systems in Malaysia which provide many functions for the survival of natural and human systems. The total internal water resources of Malaysia are estimated at 580 km^3/year (Food and Agriculture Organization of the United Nations, 2011). In addition, about 97% of the raw water supply for agricultural, domestic and industrial activities comes from surface water sources primarily rivers (Freshwater, 2008). However, water pollution and water shortage still pose a serious threat in certain parts of Malaysia. In 1995 only 41.7% of Malaysian rivers were classified as 'clean' (Malaysia Alloexpat, 2016). This shows the importance of river protection in order to obtain sustainable water usage.

Massive industrial development in recent years, and an increase in urbanisation, water pollution are of growing concern and the major contributors to water pollution are agriculture, agro-based industries such as the processing of palm oil and rubber, food processing plants and many of which discharge effluents directly into rivers. Municipal sewage dumped into rivers is also a major contributor to water pollution. Pollutions lead to deterioration of water quality with extreme values of pH, decrease in dissolved oxygen (DO) but increase in suspended solids (SS), total dissolved solids (TDS), chemical oxygen demand (COD), conductivity, colour, turbidity, ammoniacal nitrogen (NH3-N), total coliform, *E. Coli* and particles.

The conventional water treatment methods in Malaysia include processes such as coagulation, flocculation, sedimentation and filtration. The degree of the treatment depends on the nature of the source water. However, this treatment process needs extra usage of chemicals such as coagulant to treat the heavily contaminated water. Thus, high concentration of chemicals in the treatment process can be dangerous for human health (Rashid et al., 2016). Therefore, a sustainable water treatment process such as a riverbank filtration (RBF) is recommended to be used in areas with polluted water bodies.

In 2013, Malaysia has started to use the RBF in water treatment plants at Jeli, Kelantan and Kuala Kangsar, Perak. The RBF media consists of gravel and sand strata (Rashid et al., 2016). RBF is one of the cost-effective pretreatment processes and is capable to remove suspended solids, organic and inorganic pollutants (Ahmed and Marhaba, 2016). Moreover, RBF takes advantage of the infiltration of river water into a well through the riverbed and underlying aquifer material due to the pumping from wells adjacent to the surface water body (Hiscock and Grischek, 2002). The surface water from river, channel or lake is induced to flow through the natural porous medium (aquifer) by pumping process from nearby production wells (Schubert, 2002). During the RBF operation, the attenuation of the contaminated water concurrently occurred through processes such as straining or filtration, adsorption, biodegradation, ion exchange, oxidation/reduction and additional treatment steps (Dalai and Jha, 2014).

The effectiveness of the RBF treatment is mainly depends on the physical characteristics of the river water and the type of the media used. Natural zeolite is a hydrated aluminosilicate minerals that have large open pores in very regular arrangement (Woodford, 2016). Physico-chemical properties of zeolite such as ion-exchange, molecular sieving and adsorption are good for removing impurities, organic and inorganic substances from the aqueous solutions (Shaobin and Yuelian, 2010). Therefore, the media of the riverbank can be modified based on the limitations of the particular RBF system and could be used as treatment or pretreatment process in treating source water from river.

1.2 Problem Statement

Although Malaysia is blessed with plenty of unpolluted surface water, the drastic increase in population, agricultural activities, industrialisation and urbanisation has reduced the clean water sources. To overcome the problem, Malaysia has implemented alternative water treatment method such as riverbank filtration in 2013 in Jeli, Kelantan and Kuala Kangsar, Perak. Until now, we still require extensive research to improve the performance of this RBF method. Application of RBF systems may be site specific based on the local conditions and the quality of the river water in different places may encounter different limitations which require specific modification. In order to improve the RBF system, more efficient and economically feasible compounds need to be included into the treatment process. Hence, this study was conducted to evaluate the performance of zeolite as adsorbent to remove solids, total coliform, *E. Coli*, UV_{254}, colour and turbidity in river water through RBF system. Since, as zeolite is good for removing impurities such as organic and inorganic substances due to its physico-chemical properties such as ion-exchange, molecular sieving and adsorption, this media may help to improve source water quality from river as opposed to the conventional pumping of the river intake point. Column study will be conducted in this research.

1.3 Objectives

The main objectives of this study are :

1. To determine the physical and chemical characteristics of Zeolite as adsorbent.
2. To examine the removing performance of solids, total coliform, *E. Coli*, UV_{254}, colour and turbidity using zeolite in the filter column that resemble the RBF system.

1.4 Scope of Work

This study focuses on determining the removal performance of solids, total coliform, *E. Coli*, UV_{254}, colour and turbidity using Zeolite in the filter column study.

Zeolite characteristics study was first carried out to determine its physical and chemical characteristics. Next, water characteristics study was carried out to determine the physical characteristics and biological contaminants of water from Sungai Kerian. Column study was carried out using natural zeolite as porous media to remove the contaminants in water samples. This column study was conducted for 17 days with flow rate of 16.07 mL/min and retention time of 34 min to achieve optimum removal of pollutants. The removal efficiencies were determined by comparing the concentration of the selected parameters before and after the test.

1.5 Dissertation Outline

This dissertation contains five chapters:

Chapter 1 explains more on the background, problem statement, objectives and scope of this study. It gives an overview of the study.

Chapter 2 discusses the literature review about riverbank filtration, mechanisms in porous media, zeolite media, parameters examined for river water characteristics study and zeolite removing performance.

Chapter 3 covers the methodology used in this research. It includes zeolite preparation, zeolite characteristic study using SEM and XRF, river water sampling, river water characteristics study, column set up, influent characteristics study, column packed test, effluent characteristics study and desorption test.

Chapter 4 presents the results obtained from the experimental works. The results are presented in graphical form and analysis and discussion are made in detail.

Chapter 5 concludes the findings of the research and provide recommendations for improvement in future studies.

CHAPTER 2

LITERATURE REVIEW

2.1 Overview

Most of the pollution of river water in Malaysia is mainly caused by an increase in urbanization, which released effluents from residential, commercial, agricultural and industrial areas, directly into rivers. In addition, the pollution which come either in the form of point or non-point sources tends to affect the river water characteristics and contributed to the increase of organic and inorganic contaminants, temperature and pathogens in the natural water body.

Riverbank filtration (RBF) is a low-cost water treatment system that can improve water quality through physical, chemical and biological processes that occur during ground passage. Riverbank filtration includes both groundwater and river water that has percolated through the riverbed to an extraction well (Dalai and Jha, 2014). The percolation of the river water takes place through the head difference or hydraulic gradient between river water and groundwater (Caldwell, 2006). During the process of riverbank filtration, several processes such as straining or filtration, adsorption and biodegradation will occur (Dalai and Jha, 2014). According to Jaramillo (2012), this processes are to treat and filtered out the particles, microorganisms (eg. coliform), natural organic matter and organic contaminants, and inorganic compounds from a particular water source.

However, the effectiveness of the RBF treatment is mainly depends on the physical characteristics of the river water and the type of the media used. Therefore, in order to improve the riverbank filtration system, the study of the media is important to increase its efficiencies of the system. Therefore, this study focuses on zeolite as porous to be used in the RBF system.

2.2 Riverbank Filtration (RBF)

RBF is a cost-effective, natural pretreatment technology that can pretreat surface water and groundwater supplies by using filtration process instead of using chemicals (Gary, 2009). Dalai and Jha (2014) stated that riverbank filtration takes advantage of the infiltration of river water into a well through the riverbed and underlying aquifer material which is called a natural filtration process in which physico-chemical and biological processes play a role in improving the quality of percolating water. In natural filtration, the percolation takes place due to the head difference or hydraulic gradient between river water and groundwater (Caldwell, 2006).

The schematic diagram of riverbank filtration (RBF) is shown in Figure 2.1. From the diagram, the river water will infiltrated into the soil or aquifer and several mechanisms such as straining, adsorption and biodegradation are responsible to treat the polluted water. Moreover, pumping wells are installed in this zone to pump or extract the water to be used for drinking and other purposes.

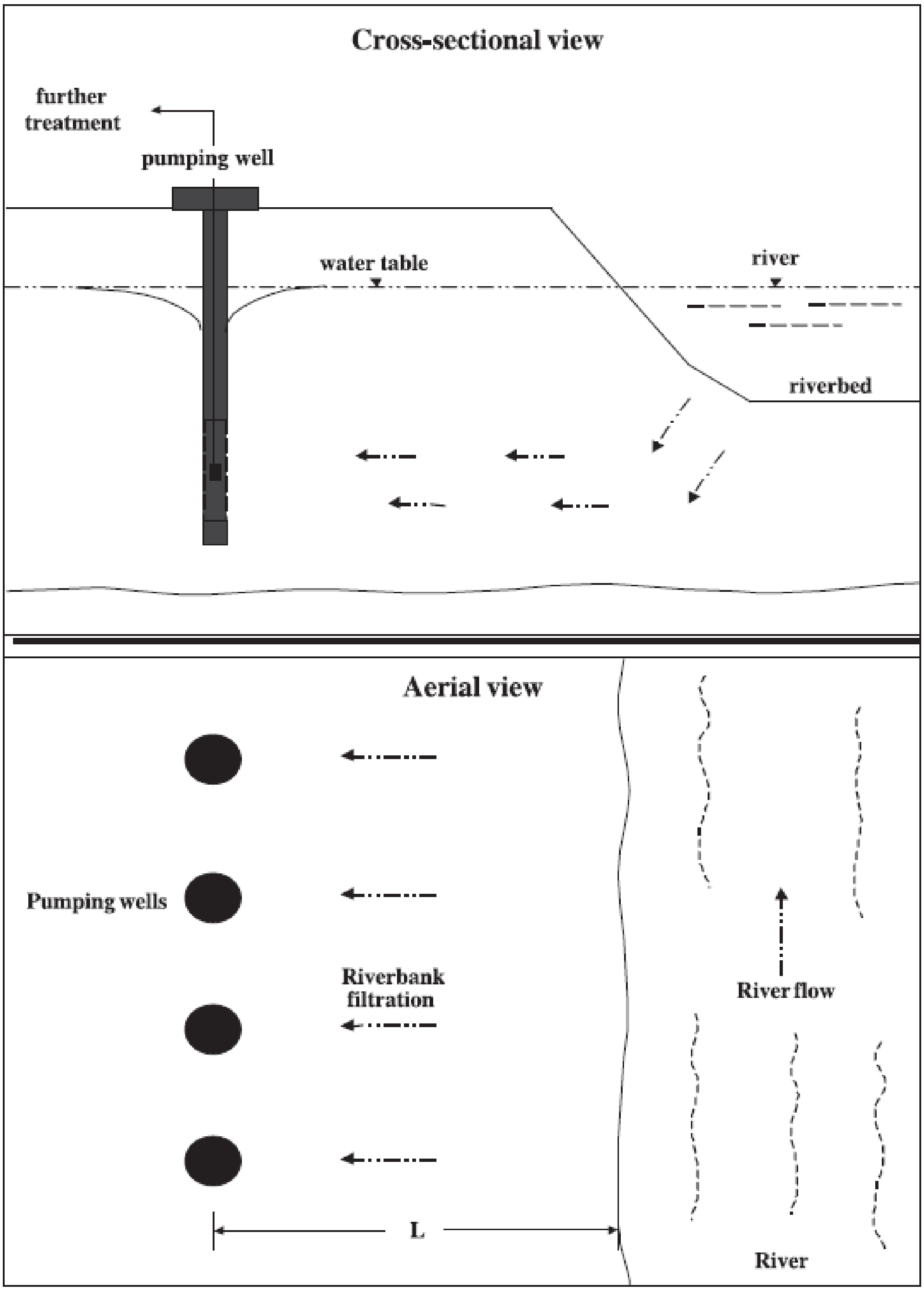

Figure 2.1 : Schematic diagram of riverbank filtration (Kim et al., 2003)

RBF has many benefits and advantages such as pretreatment through bank filtration which can remove suspended solids, organic pollutants, microorganisms, heavy metals and nitrogen. It helps to reduce chemical usage for pretreatment and resistance to contaminant threats. Moreover, it has minimal colour, odour, turbidity, algae, features a low profile and is aesthetically pleasing (Gary, 2009). Based on the study at Merrymack River, RBF was shown to be an excellent barrier against microorganisms and it removed organic precursors by an average of 63% (Gary, 2009). The study from Singh, et al. (2010), proved that the RBF is an effective device to attenuate the quality of the water which the organic contaminants, colour, UV-absorbance and coliform bacteria, which reduction around 50% in the filtrate. The technology is cost effective natural treatment process that can reduce costs for subsequent treatment (Schimdt et al., 2003b). Furthermore, RBF provide easy implementation and little maintenance technology (depending on purpose of output water) (Huelshoff et al., 2009).

On the other hand, there are several factors that can affect the performance of the RBF such as the source water quality, temperature, predominant redox conditions in the aquifer, the capability of the indigenous microbial community, and aquifer properties (Grunheid et al., 2005). The removal of biological contaminants using RBF can become more efficient if the groundwater velocity is slow and when the aquifer consists of granular materials with high grain surface contact. Many organic micro pollutants can be reduced or even eliminated during both aerobic and anaerobic underground passages (Mueller et al., 2010; Maeng et al. 2009). Furthermore, the seasonal and temperature changes in the river can result in highly dynamic changes of aerobic and anoxic conditions and as a consequence variable microbial activities in RBF systems (Massmann et al., 2008; Storck et al., 2012; Li et al., 2012). Temperature can affects biological activity, hydrological parameters, and physical properties which can play a significant role in the attenuation efficiency of RBF systems (Li et al., 2014). The water contaminant removal mechanisms and efficiency in RBF are summarized in Table 2.1.

Table 2.1 : Summary of Water Contaminant Removal Mechanisms and Efficiency in Riverbank Filtration (Sprenger et al., 2011)

Water quality parameter			Removal process	Overall removal efficiency	Reference
Physico-chemicals		Suspended solids	Straining, Van-der-Waals forces	Good	Wang, 2003; Schubert, 2002
		DOC	Biodegradation, sorption	Good	Gruenheid et al. 2005; Miettinen et al. 1996
	Nutrients	Nitrogen	Nitrification, denitrification, sorption, annanmox, mineralisation, assimilation	Moderate	Bohlke et al., 2006; Ray et al., 2002a, 2002b
	Inorganic	Pb, Cu, Zn, Cd, As, Fe, Mn, Se, Cr, U, F	Sorption, precipitation and ion exchange	Inconsistent	Schmidt et al., 2003
Biological	Pathogens	Protozoa	Straining, inactivation, die-off	Good	Berger, 2002; Tufenkji et al., 2004
		Bacteria	Sorption, die-off	Good	Dash et al., 2008; Schijven, 2002
		Virus	Sorption, inactivation	Good	Schijven et al., 2003; Havelaar et al., 1995

Micropollutants	Organics	Pesticides	Degradation, sorption	Inconsistent	Schwarzenbach et al., 1983; Verstraeten et al., 2003
		Pharmaceuticals	Degradation	Inconsistent	Heberer et al., 2004; Massmann et al., 2008
		Hydrocarbons	Degradation	Inconsistent	Juttner, 1999; Schwarzenbach et al., 1983

From Table 2.1, it shows that the RBF system has high tendency to remove pollutants such as suspended solids, dissolved organic carbon, pathogenic microorganisms, organic and inorganic pollutants during underground passage due to its straining, filtration, adsorption and biodegradation capabilities.

Although RBF can provide many benefits, but it also has its own limits. High organic pollution and higher mean temperatures both promote microbial growth and may lead to oxygen depletion, thus lowering the removal efficiencies (Huelshoff et al., 2009). Other than that, different redox conditions may cause undesirable effect to the water quality such as increase in hardness, ammonium, dissolved iron and manganese concentrations, formation of hydrogen sulphide and other malodorous sulphur compounds (Hiscock and Grischek, 2002).

RBF also tends to obstruct or clog in the porous media. There are four types of clogging which are mechanical, physical, chemical and biological. Mechanical clogging is defined as the blocking of flow through porous media due to the entrapment of gas that is dissolved into the porous media, thus preventing the water from making its way through the aquifer (Zhou et al., 2010). Physical clogging is caused by the continual percolation of river water containing suspended matter due to well pumping (Schubert, 2006a). Next, biological clogging is caused due to excessive biomass accumulation in the riverbed (Engesgaard et al., 2006). It has been found that microorganisms grow in micro-colonies, and that plugs of biomass are responsible for bioclogging (Seifert and Engesgaard, 2007). Lastly, chemical clogging is caused by the precipitation of compounds into the pores of the aquifer. Some factors thought to influence chemical clogging are iron, ammonia, nitrate concentrations, and the hardness of the water (Caldwell, 2006). Moreover, polar, persistent organic substances are often not completely removed during underground passage (dependent on residence time, length of subsoil passage, redox status) (Schmidt et al. 2003).

2.3 Mechanisms in Porous Media

The effectiveness of RBF treatment depends on several applicable processes such as straining or filtration, adsorption, biodegradation, ion exchange, oxidation/reduction and additional treatment steps (Dalai and Jha, 2014). For riverbank filtration, the mechanisms in the porous media includes the combination of straining, adsorption and biodegradation (Ray et al, 2002a).

Aronino et al. (2009) wrote that adsorption is defined as the sum of electrostatic, hydrophilic and steric interactions between the particles and the media. The interactions that take place between the microorganism and the soil particles depend on their surface characteristics (Schijven et al., 2000). The permanent infiltration of river water into the aquifer may limit the effectiveness of sorption processes in the RBF because the subsoil tends toward saturation of the adsorbents (mainly humic acids) (Schubert, 2006a).

On the other hand, straining is a physical removal process that depends on the size of the pore and the size of microbial particles. Straining process occurs when the particles in the porous media cannot pass through smaller pore, hence their transport is stopped. According to Bradford et al. (2002), the physical removal of microbial particles is influenced by the type of filter media which contributes to different grain size, amount of filter clogging and also content of particles in the water. In addition, based on recent study, physical factor such as velocity also tends to influence the colloid straining in the porous media. From the study, the straining increase when the flow velocity decrease (Bradford et al., 2007; Johnson et al., 2007). Next, based on the study by Berger (2002), straining of bacteria and viruses is less effective than for protozoa due to their smaller size.

Biodegradation is a process of biological transformation of organic material into more basic compounds and elements such as carbon dioxide and water by bacteria, fungi and other microorganisms. In addition, biodegradation is the only sustainable removal processes which the main driver for redox processes occurring during subsurface passage. This process is responsible for the breakdown of dissolved organic matter (SSWM, 2016).

2.4 Natural Zeolite

Natural zeolite is a hydrated aluminosilicate minerals made from interlinked tetrahedral of alumina (AlO_4) and silica (SiO_4). It consists of three-dimensional crystal structure built from the elements such as aluminum, oxygen, and silicon, with alkaline-Earth metals (such as sodium, potassium, and magnesium) plus water molecules trapped in the gaps between them. Zeolite form with many different crystalline structures, which have large open pores in a very regular arrangement (Woodford, 2016). Furthermore, the volume of empty spaces in the zeolite structure ranges from 20 to 50 percent of the total volume of the zeolite (Barlokova, 2008).

Natural zeolite has a structure with physico-chemical properties, such as cation exchange, molecular sieving, catalysis and adsorption. Various natural zeolites around the world have shown varying ion-exchange capacity for cations such as ammonium and heavy metal ions and some zeolites also shown adsorption of anions and organics from aqueous solution (Shaobin and Yuelian, 2010). This ion exchange and adsorption properties are good for removing impurities at low concentrations especially in the column process (Caputo and Pepe, 2007). Furthermore, zeolites also can act as catalyzing and has thermal stability and resistance in different chemical environments (Akimkhan, 2012).

Zeolite possesses high cation exchange capacity (CEC) due to the formation environment and also cation selectivity, higher void volume, and great affinity for $NH4^+$ (Dixon and Weed, 1989 ; Shaobin and Yuelian, 2010). The negative charge within the pores is neutralized by positively charged ions (cations) such as sodium, potassium and calcium. Thus, the positively charged ions that has been attracted will then be trapped and eliminated from the body (Rozic et al., 2000). Therefore, zeolites are good for removal of ammonium and heavy metal due to the surface of zeolite which is hydrophilic with regular aligned molecular level pores and cationic exchange ability, which makes it a good adsorbent for ammonia, metallic ions and catalysts (Ono and Yashima, 2000).

The efficiency of water treatment by using zeolite depends on the type, quantity and the size distribution of zeolite particles. It also depends on the initial concentration of contaminants (cation/anion), pH of solution, ionic strength of solution, temperature, pressure, contact time of system zeolite/solution and the presence of other organic compounds and anions (Margeta et al., 2013). Based on the obtained results by Moussavia et al.(2011), zeolite showed best performance for simultaneous removal of ammonia and humic acid at the pH close to that of natural waters. Natural and modified zeolites also shows good performance of ammonium removal up to 97% (Margeta et al., 2013). According to Shaobin and Yuelian (2010), there are several modification of natural zeolites can be done such as acid treatment, ion exchange, and surfactant functionalisation, making the modified zeolites achieving higher adsorption capacity for organics and anions.

2.5 River Water Quality

In this study, the following river water quality were investigated include temperature, solids (particles, SS and TDS), dissolved oxygen (DO), pH, conductivity, true colour, ammoniacal nitrogen (NH3-N), UV_{254}, turbidity, dissolved organic carbon (DOC), chemical oxygen demand (COD), total coliform, and *Eschrichia coli* (*E. Coli*).

Temperature of water can influence the biological activity and growth of living organism that live in the lake and river. Water temperature is an important factor because it can affect metabolic rates, photosynthesis production, compound toxicity, dissolved oxygen and other dissolved gas concentrations, water density and also conductivity and salinity (Fundamentals of Environmental Measurements, 2016).

Dissolved oxygen (DO) is the amount of gaseous oxygen (O_2) dissolved in the water. Oxygen enters the water by absorption from the atmosphere, by rapid movement, or as a waste product of plant photosynthesis. Warm water can hold less dissolved oxygen compared to cold water because oxygen is hard to dissolve in warm water than in cold water. Therefore, warm water may not contain enough dissolved oxygen for the survival of different species of aquatic life (U.S. Geological Survey, 2016).

pH of water is a measurement of the concentration of Hydrogen (H^+) ions, using a scale that ranges from 0 to 14. A pH of 7 is considered neutral, since concentration of H+ and OH- ions are equal. On the other hand, pH below 7 is considered acidic because it contain more Hydrogen (H^+) ions while pH above 7 is considered alkaline because it contain more Hydroxyl (OH^-) ions. Pollution can change the pH value, which can harm animals and plants living in the water (U.S. Geological Survey, 2016). According to Gandaseca et al., (2011), river water pH that ranges from 6.5 – 9.0 at day time is the most suitable for aquatic life. Therefore, it is vital to protect the aquatic ecosystem from the pollutants with excessive acidic or basic agent to ensure the pH will remains between 6.5, 8.5 or 9.0 (Gandaseca et al., 2011).

Conductivity is a measure of water's capability to pass electrical flow and is directly related to the concentration of ions in the water (EPA, 2012). The more ions that are present in the water, the higher the conductivity will be (Perlman, 2014). However, conductivity is dependent mainly by the inorganic dissolved solids such as aluminium cations, calcium, chloride, iron, nitrate, magnesium sulphate and sodium (Gandaseca et al., 2011). Water temperature, salinity and total dissolved solid (TDS) also can affect the conductivity (Talley, 2000). When the water temperature increase, the conductivity also increase (Fundamentals of Environmental Measurements, 2016).

Dissolved organic carbon (DOC) is a general description of the organic material dissolved in water. It is a measurement of the amount of organic matter in water that can be passed through a 0.45 μm filter. Dissolved organic carbon can get into the water when decomposition of plants or animals formed organic material (including carbon) and this decomposed organic material may partially dissolve once it contacts with water (Kolka et al., 2008). Moreover, DOC can alters aquatic ecosystem chemistries by contributing to acidification in low-alkalinity, weakly buffered, freshwater systems (Monica, 2016).

Chemical oxygen demand (COD) is the amount of oxygen consumed by the organic compounds and inorganic matter which oxidized in water. The COD level reflect the pollution degree of the water, and are the comprehensive index of the relative content of organics (Yang et al., 2009). Amneera (2013) wrote that the water is considered polluted when the COD concentration is higher.

Total coliform are a group of microorganisms commonly found in the soil, in water that has been influenced by surface water, and in human or animal waste. Coliforms come from the same sources as pathogenic organisms which are relatively easy to identify and usually present in larger numbers than more dangerous pathogens. Coliforms also respond to the environment, wastewater treatment, and water treatment similarly to many pathogens (New York State Department of Health, 2011). Most coliform bacteria will not cause illness but these bacteria are used as indicators in water tests because their presents indicate that disease-causing organisms (pathogens) could also be in water (NCPH, 2009)**.**

Escherichia coli (*E. coli*) is the major species in the fecal coliform group that comprise the total coliforms and generally not found growing and reproducing in the environment. In addition, *E. coli* is considered to be the species of coliform bacteria that is the best indicator of fecal pollution and the possible presence of pathogens. Most coliform bacteria do not cause disease except for some rare strains of *E. coli*, such as strain 0157:H7, can cause serious illness (NYSDH, 2011).

Total dissolved solids (TDS) is defined as inorganic salts and small amounts of organic matter such as calcium, magnesium, sodium, potassium cations, carbonate, hydrogencarbonate, chloride, sulfate, and nitrate anions that are dissolved in water. TDS usually originates from natural sources, sewage, urban run-off, industrial wastewater, and chemicals used in the water treatment process. High TDS can result the hardness of water increases due to the presence of calcium and magnesium and also can cause undesirable taste which could be salty or bitter (Water Research Centre, 2014).

Ammoniacal nitrogen is a term referred to two chemicals species which are in equilibrium in water (NH_3, un-ionized and NH_4^+, ionized). In general, NH_3 (un-ionized form) is the principal form of toxic ammonia as opposed to the NH_4^+ (ionized form) which means that more NH_3 can increase the toxicity of water. In addition, toxic levels depends on both temperature and pH. The toxicity will increase as both pH and temperature decreases (Brian, 2014). Ammoniacal nitrogen also acts as indicator of the pollution from excessive usage of ammonia especially from fertilizers (Gandaseca et al., 2011). The excessive levels of ammonia than the recommended limits tends to harm aquatic life due to the accumulation in the organisms and cause alteration of metabolism or increases in body pH (Brian, 2014).

UV_{254} is the term used for water quality test parameter which utilizes light at the UV_{254} nm wavelength. This test is able to detect the presence of organic matter in water and wastewater due to the fact that most organic compounds absorb light at the UV_{254} nm wavelength. UV_{254} is represented as a calculation of UV absorbance (UVA) or UV transmittance (Glover, 2007).

Most of colour in water is caused by organic substances or natural metallic ions such as iron, manganese and copper. Algae and suspended sediment particles are very common particulate matter that cause natural waters to become coloured. Other than that, highly coloured water has significant effects on aquatic plants and algae growth. Light is very important for the growth of aquatic plant but coloured water can cause the light difficult to penetrate into the water. Thus a highly colored water could not sustain aquatic life (U.S. Geological Survey, 2016).

Turbidity is a measure of clarity of a liquid and the unit of measurement is nephelometric turbidity units (NTU). It is an optical characteristic of water and is an expression of the amount of light that is scattered by material in the water when a light is shined through the water sample. The higher the intensity of scattered light, the higher the turbidity. Turbidity makes the water turns cloudy and may also represent a health concern since turbidity can promote regrowth of pathogens in the distribution system (U.S. Geological Survey, 2016).

Suspended solids are particles that larger are than 2 microns which most of them are made up from materials such as silt and sand that came from erosion of urban runoff, organic particles from decomposing materials such as algae, plants and animals) and also chemical precipitation from industrial waste (Murphy, 2007). Furthermore, high concentration of suspended solids tends to absorb heat from the sunlight which can increase the water temperature and as a result, water will become warmer and lessen the ability to hold oxygen (North Dakota Department of Health, 2005). According to Vinod and Chopra (2012), water with high suspended solids is unpalatable and potentially unhealthy to human.

Water typically contains small amounts of very finely divided solid particles including conglomerate of materials, mineral matter such as clay, silt, sand, decomposing organic substances and inorganic biogenic material. Normally, the size of these solid particles are ranging from colloidal dimensions to about 100μm (Wetzel, 2001). These particles that can be carried away by water is called sediment transport. These transported sediment may include mineral matter, chemical and pollutants and also organic material. In addition, the sediment that will be conveyed will become higher if the flow of water is greater. Another name for sediment transport is sediment load. The total load includes all particles moving as bedload, suspended load, and wash load (Southard, 2006).

2.6 Summary

Based on the literature review, it can be concluded that riverbank filtration (RBF) is a water treatment system that uses natural filtration process through the riverbed to treat the polluted water. This system works by several mechanisms such as straining or filtration, adsorption and biodegradation which remove suspended solids, organic pollutants, microorganisms, heavy metals and nitrogen. However, the performance of the RBF depends on several factors such as source water quality, temperature, predominant redox conditions in the aquifer, the capability of the indigenous microbial community, and aquifer properties. Although RBF can provide many benefits, but it also has its own limits and weaknesses. Therefore, extensive researches and modifications have been carried out to improve the RBF systems in terms of its efficiency to treat polluted water. In addition, zeolite is hydrated aluminosilicate minerals that is formed with many different crystalline structures, which have large open pores in a very regular arrangement. Moreover, zeolite has a structure with physico-chemical properties, such as cation exchange, molecular sieving, catalysis and adsorption. This characteristics of zeolite are good to remove impurities, organic and inorganic materials, thus it has the potential to become a rather comprehensive modification to the RBF system. Therefore, this study is carried out to determine the potential of zeolite in the RBF system.

CHAPTER 3

METHODOLOGY

3.1 Overview

Laboratory works were conducted in this study to examine the removals performance of particles total coliform, *E. Coli*, total dissolved solids (TDS), suspended solids (SS), UV_{254}, colour and turbidity using zeolite in filter column. pH were also monitored throughout the experiments. Zeolite as the main filtering media in RBF was first characterized using Scanning Electon Microscopy (SEM) and X-Ray Fluorescence (XRF) method.

The packed column was designed resembling the RBF system that uses filtration through the porous media to treat the polluted water. Water samples were collected from Sungai Kerian, Lubok Buntar and underwent characteristics study to determine the physical characteristics and biological contaminants. The column test was conducted up to 17 days in order to determine the breakthrough curve of removal. The sampling were done before and after filtration.

After the laboratory works, the removal performance of the selected parameters were determined by calculating the removal percentage. However, for parameters that show negative removal percentage, the desorption test was conducted at optimum condition of 40 g of porous media, 200 rpm of shaking speed and 105 minutes of contact time. This test was conducted to determine if impurities from the zeolite is released into the water, thus effect the removal efficiencies. The overall methodology of the research is summarized in Figure 3.1.

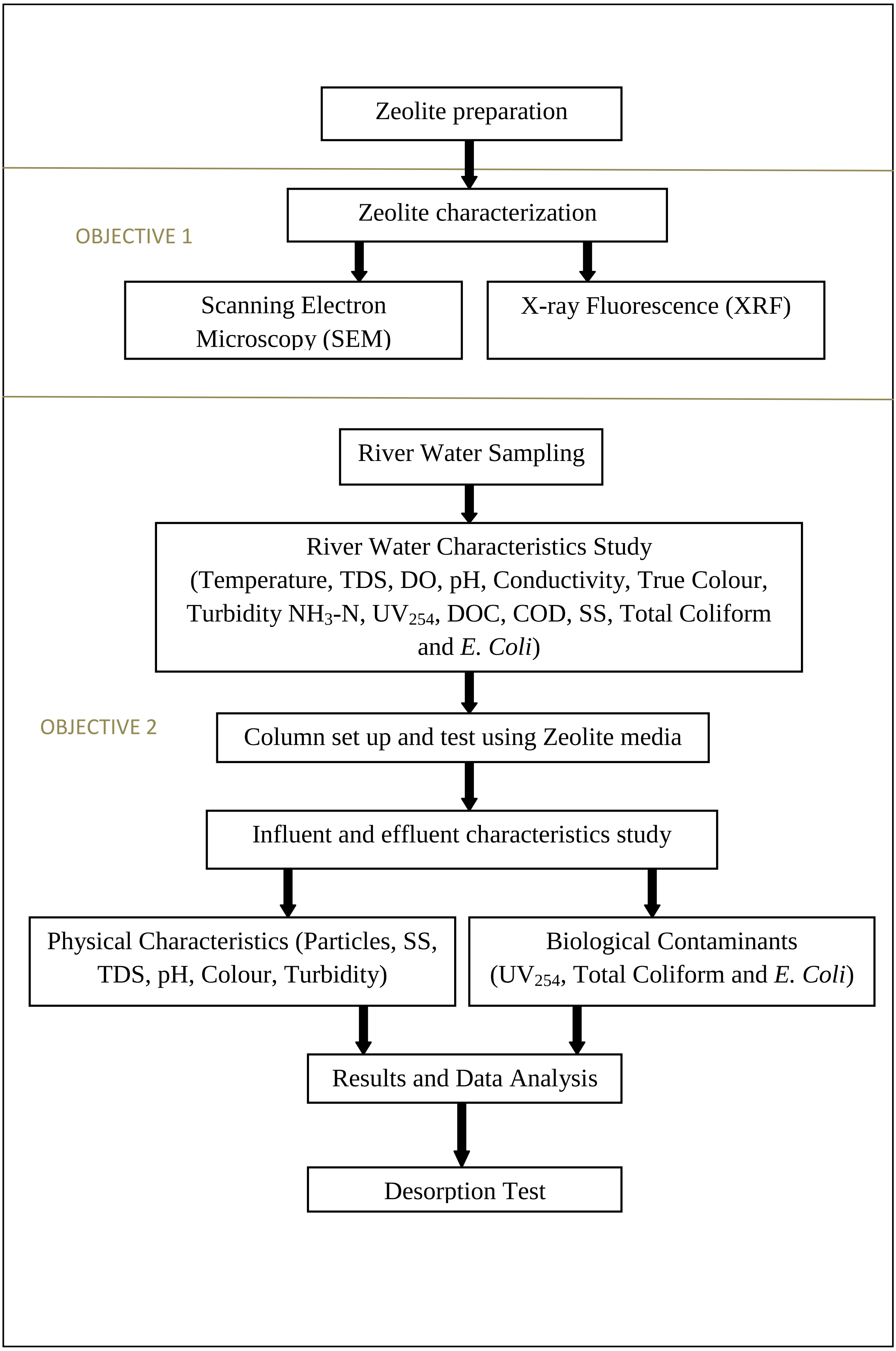

Figure 3.1 : Flow Chart of Methodology

3.2 Zeolite Media Preparation

The natural zeolite which is originated from Indonesia were crushed and sieved to working size of 1.18mm-2mm in accordance to ASTM E11-15. After that, the zeolite was washed using distilled water to remove the impurities. Instead of using tap water, distilled water were used to avoid contaminant to the zeolite. After the cleaning process, zeolite was oven dried (105 ℃) for 24 hours to remove all the moisture content. Lastly, the zeolite was stored in air tight container for later use.

3.3 Zeolite Characteristics Study

Physical and chemical characterization of zeolite were carried out using Scanning Electron Microscopy (SEM) and X-ray Fluorescence (XRF) instrument. These test were carried out for both before and after the column study.

3.3.1 Scanning Electron Microscopy (SEM)

The Scanning electron microscopy (SEM) is important to determine the external morphology (texture), chemical composition, crystalline structure and orientation of materials making up the zeolite. The SEM model used for the test was ZEISS SUPRA 35VP. This SEM instrument used a focused beam of high-energy electrons to generate a variety of signals at the surface of solid specimens. The signals that derive from electron-sample interactions reveal information about the sample. The sample was first coated with a composite film of carbon or metal to ensure electrical conductivity and thus prevent charging effects in the microscope. The data were collected over a selected area of the surface of the sample, and a 2-dimensional image is generated that displays spatial variations in these properties (Sharmila, 2003).