TREATMENT OF HARVESTED RAINWATER FROM DIFFERENT LOCATION OF CATCHMENT AREA BY USING ZEOLITE, LIMESTONE AND LATERITE SOIL

KHAIRUNNISA FAKHRIAH BINTI MOHD OMAR

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Treatment of Harvested Rainwater from Different Location of Catchment Area by Using Zeolite, Limestone, and Laterite Soil

by

KHAIRUNNISA FAKHRIAH BINTI MOHD OMAR

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LIST OF SYMBOLS

$1/n$	Adsorption intensity
b	Langmuir constant, L/mg
C	The value intercept from the linear
C_e	Final equilibrium concentration of adsorbate after adsorption has occurred, mg/L
C_o	Initial concentration of adsorbate, mg/L
k_1	Rate constant of pseudo-first order adsorption (1/min)
k_2	Rate constant of pseudo-second order adsorption (g/mg/min)
k_3	Intra particle diffusion rate constant (mg $g^{-1}min^{1/2}$)
K_F	Indicator of the adsorption capacity
m	Mass of adsorbent, g
q_e	Adsorbent phase concentration after equilibrium, mg/g adsorbent
Q_m	Maximum adsorption capacity, mg/g
q_t	The amount of adsorbate adsorbed (mg/g) at time t (min)
R_L	Equilibrium parameter
$t^{0.5}$	The square root of time ($min^{1/2}$)
V	Volume of liquid in the reactor, L

LIST OF ABBREVIATIONS

Ar (III)	Arsenic (III)
BET	Brunaue-Emmett-Teller (BET) pore size analysis
$CaCO_3$	Calcium carbonate
Cd (II)	Cadmium (II)
COD	Chemical oxygen demand
Cr (VI)	Hexavalent Chromium
Cu^{2+}	Copper (II) ions
DOC	Department of Chemistry
DOE	Department of Environment
EDX	Energy Dispersive X-ray Spectroscopy
E.coli	*Escherichia coli*
H^+	Hydrogen cations
HCl	Hydrochloric acid
INWQS	Interim National Water Quality Standard
NDWQS	National Drinking Water Quality Standard
$MgCO_3$	Magnesium carbonate
NaOH	Sodium hydroxide
NH_3-N	Ammoniacal Nitrogen
OH^-	Hydroxide ions
REPAS	Western Pacific Regional Centre for the Promotion of Environmental Planning and Applied Studies
RWH	Rainwater harvesting system
SEM	Scanning Electron Microscopes
Soco-dis	Solar collector disinfection
SODIS	Solar disinfection

TOC	Total organic compound
WHO	World Health Organization

RAWATAN AIR TADAHAN HUJAN DARIPADA LOKASI TADAHAN YANG BERBEZA DENGAN MENGGUNAKAN ZEOLITE, BATU KAPUR DAN TANAH LATERIT

ABSTRAK

Malaysia dikurniakan jumlah air hujan yang banyak. Walau bagaimanapun, ia tidak digunakan sepenuhnya dan dibiarkan sebagai air permukaan. Secara umum, air hujan mempunyai pencemaran dalam kepekatan yang rendah. Oleh itu, satu rawatan air diperlukan untuk menggunakan air hujan sebagai sumber alternatif air minuman. Kajian ini dijalankan bagi menyiasat prestasi 3 jenis penjerap semulajadi yang berasaskan sumber mineral. Penjerap yang digunakan ialah zeolite, batu kapur, dan tanah laterit untuk mengeluarkan bahan pencemar daripada air hujan seperti keperlun oksigen kimia (COD), kekeruhan, mangan, besi, plumbum, dan bakteria *E.coli*. Kajian awal berkumpulan telah dijalankan untuk setiap jenis bahan pencemar dan penjerap. Berdasarkan keputusan kajian, zeolite mempunyai potensi untuk mengeluarkan COD, mangan, dan plumbum ketika dijalankan dalam keadaan optimum. Peratusan pengeluaran oleh zeolite untuk bahan pencemar COD, mangan, dan plumbum masing - masing adalah 74%, 80%, dan 79%. Dalam kajian ini, batu kapur telah menunjukkan keputusan yang baik untuk pengeluaran logam berat seperti mangan, besi dan plumbum. Selain daripada itu, batu kapur berupaya untuk mengeluarkan bakteria *E.coli* pada keadaan optimum, iaitu sebanyak 99%. Walaubagaimapun, batu kapur kurang berupaya untuk mengeluarkan COD memandangkan peratusan yang diperolehi sebanyak 48% sahaja. Penggunaan tanah laterit sebagai penjerap turut dikaji. Kajian menunjukkan tanah laterit mempunyai potensi yang baik dalam mengeluarkan bahan pencemar dalam keadaan yang optimum. Peratusan pengeluaran bagi COD, kekeruhan, bakteria *E.coli*, mangan, besi, dan plumbum oleh tanah laterit adalah 56%, 83%, 99.6%, 89%, 83%, dan 76.8%. Kajian ini turut menganalisis penjerapan isoterma model dan juga penjerapan kinetik model untuk setiap parameter dan juga penjerap. Penggunaan tanah laterit sebagai media tapisan untuk kajian penapisan ruangan adalah kerana prestasi yang bagus dalam eksperimen kajian awal. Kajian penapisan ruangan telah dijalankan dengan menggunakan kadar aliran sebanyak 20mL/min dan kedalaman penjerap setinggi 300mm. Kajian ini menunjukkan tanah laterit masih mampu mengeluarkan bakteria *E.coli* walaupun eksperimen telah dijalankan selama 58 hari berterusan, di mana kepekatan E.coli dalam air hujan hampir memenuhi kepekatan yang dibenarkan seperti yang dinyatakan di dalam *"Malaysian Drinking Water Guidelines".* Justeru itu, air hujan didapati mempunyai potensi sebagai air minuman sekiranya ia telah dirawat dengan tanah laterit.

TREATMENT OF HARVESTED RAINWATER FROM DIFFERENT LOCATION OF CATCHMENT AREA BY USING ZEOLITE, LIMESTONE, AND LATERITE SOIL

ABSTRACT

Malaysia is blessed with huge amount of rainwater. However, the rainwater is not fully utilized and is abandoned as surface runoff. Generally, rainwater has low concentration of pollutants. A treatment is necessary prior to utilize the rainwater as a source of drinking water. This study was carried out to determine the performance of three natural mineral adsorbents, namely zeolite, limestone, and laterite soil to remove pollutants such as COD, turbidity, manganese, iron, lead, and *E.coli*. Preliminary batch studies were conducted to determine the optimum conditions for each parameter and adsorbents. Based on the results, zeolite was able to remove COD, manganese and lead at optimum condition with percentage removal of 74%, 80%, and 79%, respectively. In this study, the performance of limestone was undoubtedly shown good removal of heavy metals (namely manganese, iron, and lead). Besides, the limestone also has good removals on *E.coli* at optimum condition with 99% removal. However, limestone has poor removals for COD with only 48% of percentage removals. The performance of laterite soil was determined and the results demonstrated that it performs a good removal for all the parameters at optimum condition. The percentage removals of COD, turbidity, *E.coli*, manganese, iron, lead by laterite soil were 56%, 83%, 99.6%, 89%, 83%, and 76.8%, respectively. In this study, adsorption isotherm model and adsorption kinetic model were determined for the removals of each parameter by the adsorbents. Laterite soil was chosen as a filter media in column study to remove *E.coli* due to the good performance in batch study. The column study was conducted with 300mm bed depth and 20 mL/min of flow rate. The results demonstrated a good performance as the removal of *E.coli* was continuously occur with the percentage removal of 90 - 99% after 58 days of treatment, whereby the final concentration of E.coli almost complied with the allowable concentration as stated in *"Malaysian Drinking Water Guidelines".* Therefore, the study discovered that the rainwater has shown the potential as drinking water after being treated by laterite soil.

CHAPTER ONE

INTRODUCTION

1.1. General

Water shortage problems have been discussed around the world. It has been identified that the freshwater and scarcity and security is one of the major global environmental problems of the 21st century as the water crisis may kill 34 to 76 million people by 2020 (Cain, 2010; Srinivasan *et al.*, 2012). It is estimated the accessibility of renewable freshwater is limited due the increasing global populations about 9 billion by 2050 (Gleick and Palaniappan, 2010). In Malaysia, the water resources are fully dependent on treated fresh water from the main sources such as river water, storage dam, and groundwater (Che-Ani *et al.*, 2009; Sukereman, 2013).

In 1998, Malaysia faced severe drought and it lead to an unpleasant water supply disruption. The Klang Valley and certain states in Malaysia such as Melaka, Selangor, Kedah, Kelantan, Sabah, and Sarawak were affected during this water crisis. It was reported that there were about 1.8 million residents in the Klang Valley and 170,000 residents in Sabah who faced water disruption problems from this phenomenon (Lee *et al.*, 2016).

Additionally, increasing water demand has become a major contributor to water shortage problems. Population growth combined with the expansions in urbanization, industrialization and irrigated agriculture has increased daily water consumption (Sukereman, 2013). Law and Bustami concluded that the water consumption among Malaysians increased to more than 300L per capita per day, which leads to the increase of water demand (Law and Bustami, 2013).

Further, the low quality of freshwater from main source such as river is also contributed to water crises. The authorities in Malaysia have reported that a primary water treatment plant in Selangor was closed in January 2014 from increased ammonia content in the Langat River. In a nutshell, the three major factors as discussed above have given a major impact in water resources. Due to that, it is important to find an alternative source for water supply such as rainwater.

Rainwater is precipitation in liquid form that comes from the moisture in the clouds and falls to the earth's surface. It can be considered as the purest water in the world (Biswas and Mandal, 2014). However, every drop of rainwater picked up particles and impurities that exist in the air. These impurities able to change the purity of the rainwater drastically as it reaches the earth (Aziz *et al.*, 2016). Rainwater that flows on the top of the soil can be defined as surface runoff (Drgoňová *et al.*, 2016).

Rainwater harvesting system is a system to collect and store rainfall from roofs or other surface catchment for later usage (Nzewi *et al.*, 2010). Generally, domestic rainwater harvesting system is commonly used throughout the world. It consists of a collection area (roof area) and conveyance system such as gutters, storage systems, and plumbing systems (Li *et al.*, 2010). Rainwater harvesting system has many advantages for a sustainable living. It is capable to reduce urban