UTILIZATION OF ZELIAC AS AN ALTERNATIVE ADSORBENT TO REMOVE LOW LEVEL CONCENTRATION OF NOM IN RIVERBANK FILTRATION

by

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LIST OF ABBREVIATIONS

Al_2O_3	Aluminum oxide
BET	Brunauer-Emmet-Teller
C	Carbon
Ca	Calcium
CaO	Calcium oxide
COD	Chemical Oxygen Demand
DBPs	Disinfection by-Products
DO	Dissolved Oxygen
DOC	Dissolved Organic Carbon
DOE	Department of Environment
EBCT	Empty Bed Column Time
Fe	Ferum/ Iron
Fe_2O_3	Iron oxide
FTIR	Fourier transform infrared
H_2SO_4	Sulphuric acid
HAAs	Haloacetic acids
HCl	Hydrochloric acid
HLR	Hydraulic Loading Rate
HNO_3	Nitric acid
ICP-OES	Inductively Coupled Plasma Optical Emission Spectrometry
K_2O	Potassium oxide
LBWTP	Lubok Buntar Water Treatment Plant
Mg	Magnesium

MgO	Magnesium oxide
Mn	Manganese
MOH	Ministry of Health
Na_2O	Sodium oxide
NaOH	Sodium hydroxide
NH_3-N	Ammonia nitrogen
NOM	Natural Organic Matter
NWQS	National Water Quality Standards
POC	Particulate Organic Carbon
RBF	River Bank Filtration
SADA	Syarikat Air Darul Aman Sdn. Bhd
SEM	Scanning Electron Microscopy
SiO_2	Silicon dioxide
SO_3	Sulfur trioxide
SPC	Specific Conductivity
SS	Suspended Solids
SUVA	Specific UV Absorbance
TDS	Total Dissolved Solids
THMs	Trihalomethanes
TOC	Total Organic Carbon
USM	Universiti Sains Malaysia
UV_{254}	UV Absorbance at Wavelength of 254 nm
WTP	Water Treatment Plant
XRD	X-ray Diffraction
XRF	X-Ray Fluorescence

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PENGGUNAAN ZELIAC SEBAGAI PENJERAP ALTERNATIF BAGI PENYINGKIRAN BAHAN ORGANIK SEMULA JADI BERKOSENTRASI RENDAH DALAM TAPISAN TEBING SUNGAI

ABSTRAK

Peningkatan bahan organik semulajadi (NOM) dalam air permukaan adalah membimbangkan kerana ia merupakan bahan utama kepada produk sampingan disinfektan (DBP) dalam sistem olahan air minuman konvensional yang boleh membahayakan kesihatan. Manakala, tapisan tebing sungai (RBF) adalah pilihan yang baik untuk mengurangkan pencemaran air permukaan dan mengatasi masalah kekurangan air terutamanya semasa keadaan cuaca yang melampau seperti kemarau dan banjir. Oleh itu, tujuan kajian ini adalah untuk mengurangkan kemungkinan pembentukan DBP dengan mengawal tahap NOM dalam air dan pada masa yang sama merawat bio-koloid dan bahan pencemar ionik dengan menggunakan bahan penjerab komposit *Zeliac* secara RBF. Hasil pemantauan kualiti air menunjukkan bahawa NOM di Sungai Kerian mencatatkan purata 3.6 mg/L DOC dan 0.10 cm^{-1} UV_{254}. Total koliform didapati melebihi standard kualiti air mentah dengan kepekatan purata $1.5x10^{4}$ MPN/100 mL. Nilai purata UV_{254} (0.03 cm^{-1}) yang sama diperolehi bagi air dari RBF dan LBWTP. Pada masa yang sama, tahap DOC yang lebih tinggi diukur dari air terawat (1.6 mg / L) berbanding RBF (0.81 mg / L). Untuk bio-koloid, tiada *E. coli* dikesan dalam air dari RBF, namun bakteria koliform masih hadir. Kepekatan parameter lain juga telah berkurangan kecuali Fe dan Mn. Hasil kajian ini menunjukkan bahawa air yang diambil dari RBF masih memerlukan rawatan lanjut bagi memastikan air tersebut selamat dan bersih untuk kegunaan manusia. Kajian terhadap ciri *Zeliac* menunjukkan bahawa bahan penjerap ini mempunyai 40.6 m^2/g luas permukaan dan 16.5 nm purata saiz liang. Kewujudan Ca, Si dan Al menjadikan

Zeliac sebagai penukar kation yang baik. Di samping itu, kumpulan hidroksil dan karboksil membuktikan bahawa *Zeliac* dapat *menarik* bahan pencemar ion positif dan pada masa yang sama, kumpulan karbonil dapat membantu dalam penjerapan karbon organik. Berdasarkan, kajian isoterma dan kinetik, penyingkiran bahan pencemar dikawal oleh penjerapan ke permukaan heterogen melalui perkongsian antara bahan atau pertukaran ion. Pada dos optimum 7 g per 100 mL sampel, kecekapan penyingkiran UV_{254}, warna dan NH_3-N masing-masing adalah 72.8% (0.129-0.035 cm^{-1}), 78.6% (42-9 PtCo) dan 77.1% (0.70-0.16 mg/L). Dalam eksperimen penjerapan turus, perbezaan saiz butiran *Zeliac* didapati tidak memberikan kesan yang signifikan terhadap prestasi penyingkiran. Titik bolos untuk UV_{254} dan bio-koloid masing-masing berlaku pada 103 dan 31 jam pada kadar beban hidraulik 1 cm/min. Hasil ini menunjukkan prestasi *Zeliac* yang baik dalam menyingkirkan sebatian organik dan ionik dalam sumber air minuman serta keupayaannya sebagai media penapis alternatif dalam RBF.

UTILIZATION OF ZELIAC AS AN ALTERNATIVE ADSORBENT TO REMOVE LOW LEVEL CONCENTRATION OF NOM IN RIVERBANK FILTRATION

ABSTRACT

An increase of NOM in river water is a concern as it is the main precursor to health hazard disinfection by-products (DBPs) in conventional drinking water treatment system. River bank filtration (RBF) is a good option to reduce surface water pollution and overcome water shortage problem especially during extreme weather events such as droughts and floods. Therefore, this study aims to reduce the possibility of DBPs formation by controlling the level of NOM and treating it together with bio-colloids and ionic pollutant by composite adsorbent *Zeliac* in RBF. Water quality monitoring study shows that NOM in Kerian River recorded an average of 3.6 mg/L DOC and 0.10 cm^{-1} UV_{254}. Total coliform exceeded the raw water quality standard with an average concentration of $1.5x10^4$ MPN/100 mL. The same mean level of UV_{254} (0.03 cm^{-1}) was determined in the water from RBF and LBWTP. Meanwhile, higher level of DOC measured from final treated water (1.6 mg/L) than RBF (0.81 mg/L). For bio-colloids in RBF, no *E. coli* was present but total coliform was still detected in the water. Other determined parameters were also reduced except for Fe and Mn. This finding signifies the water abstracted from RBF well still requires further treatment to ensure the water is safe and clean for human consumption. The characteristics study of *Zeliac* shows that the adsorbent has a surface area of 40.6 m^2/g and average pore size of 16.5 nm. The existence of Ca, Si and Al makes *Zeliac* a good cations exchanger. In addition, hydroxyl and carboxyl groups proved that *Zeliac* can attract positive ions or anionic organic pollutants depending on the water sample acidity. According to the equilibrium and kinetic study, the removal of pollutants was controlled by multilayer adsorption onto heterogeneous surface of *Zeliac*. At optimum dosage of 7 g per 100 mL sample, the removal efficiency of UV_{254}, colour and NH_3-N were 72.8% (0.129 – 0.035 cm^{-1}), 78.6% (42 - 9 PtCo) and 77.1% (0.70 – 0.16 mg/L), respectively. In column adsorption experiments, it was found that granular size of *Zeliac* gave no significant effect to the removal performance. The break point for UV_{254} and bio-colloids occurred at 103 and 31 hours of experiment respectively at hydraulic loading rate of 1 cm/min. These results show a good performance of *Zeliac* in removing both organic and ionic compounds in drinking water source as well as its capability as an alternative filter media in the RBF.

CHAPTER ONE

INTRODUCTION

1.1 Background

Surface water in Malaysia are exposed to organic, inorganic and pathogenic microorganism pollutions as a result of poor management of septic tank, wastewater, agriculture products runoff and earthwork (DOE, 2015). According to the annual report by Department of Environment (DOE) Malaysia, 48% from 473 rivers monitored in 2014 were polluted by these sources. The high percentage reflected the situation where water resources in Malaysia has been deteriorated and the condition may continue to worsen. Among all pollutants load entering surface water, bio-colloids and natural organic matter (NOM) are the two major pollutants attributed by wastewater discharge and surface runoff.

NOM is a complex mixture between organic compounds generated by biological degradation processes in the water body (autochthonous materials) with organic compounds that enter the water from human activities (allochthonous materials) (Croue et al., 1999; Matilainen et al., 2011). Generally, NOM is determined in terms of dissolved organic carbon (DOC) and UV absorbance at 254 nm (UV_{254}). Meanwhile, bio-colloids usually refer to microorganism in water such as bacteria and protozoa (Crittenden et al., 2012). Elevation of NOM and bio-colloids concentration in surface water raises concern in safety of drinking water. The main concern is related to the potential formation of carcinogenic/mutagenic disinfectant by-products (DBPs) such as trihalomethanes (THMs) and haloacetic acids (HAAs) from the reaction of NOM with disinfectant (Sharp et al., 2006; Fan et al. 2014; Richardson and Postigo.

2015). According to Krasner et al, (2006) and Richardson et al, (2007), continuous consumption of DBPs can lead to cancers, miscarriages and nervous system complications. As a results, a very low concentration of DBPs was regulated for drinking water supply (Richardson, 2009). On the other hand, the increase of bio-colloids typically increases the possibility of microbial contamination (WHO, 2012). Approximately 842, 000 death cases involving diarrheal illness were reported as a result of drinking water contamination (WHO, 2016).

The situation may worsen during extreme weather events such as El Nino (drought) and El Nina (floods) which give a large impact in water resource quality and quantity (Delpla et al., 2009; Chan, 2015). According to previous studies, significant increase of NOM and bio-colloids in surface water were observed during these events (Prathumratana and Kim, 2008; Delpla et al., 2009; Hrdinka et al., 2015). This situation poses bigger challenges to the authorities in providing and delivering safe drinking water using conventional treatment system because of high pollutant loads and low surface water level (Hrdinka et al., 2012; Ching et al., 2015). Normally, optimized coagulation used for NOM removal in conventional treatment system is only capable of removing approximately 50% of NOM present in the water (Tubić et al., 2013). Therefore, an alternative method for water management is necessary to ensure safe and stable drinking water supply especially during extreme weather.

River bank filtration (RBF) is one attractive option that can be applied. RBF is a cost-effective water treatment process that is less vulnerable to climate changes or variations and is capable to remove physical, chemical and biological pollutants from surface water through natural filtration in aquifer sediments at the riverbank (Doussan et al., 1997; Grischeck et al., 2003; Ahmed and Marhaba, 2016). This technique requires a well to be drilled adjacent to a river for water abstraction. Abstracting water