PERFORMANCE OF COMPOSITE ADSORBENT-LIMESTONE/ACTIVATED CARBON/ALGINATE IN TREATING RIVER WATER

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by

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LIST OF SYMBOLS

Ce	Equilibrium concentration
C_0	Initial concentration
C_t	Concentration at t
K_F	Freundlich constant
K_L	Langmuir constant
k_1	Adsorption rate constant for pseudo-first-order
k_2	Adsorption rate constant for pseudo-second-order
M	Mass of the adsorbent
N	Number of observations
n	exponential coefficient
q_e	adsorbed amount of color and turbidity per unit weight of adsorbent
q_m	Langmuir maximum adsorption capacity
q_t	adsorption capacity at different contact time
$q_{e, cal}$	calculated adsorption capacity at equilibrium
$q_{e\ exp}$	experimental adsorption capacity at equilibrium
R^2	Coefficient of determination
$RMSE$	Root-mean squared error
t	Time

LIST OF ABBREVIATIONS

AC	Activated carbon
AG	Alginate
BET	Brunauer-Emmett-Teller
BOD	Biochemical Oxygen Demand
COD	Chemical Oxygen Demand
DBP	Disinfectant by-product
DOE	Department of Environmental
DOC	Dissolved organic carbon
EDX	Energy dispersive x-ray
FTIR	Fourier Transform Infrared Spectroscopy
GAC	Granular activated carbon
INWQS	Interim National Water Quality Standards for Malaysia
IUPAC	International Union of Pure and Applied Chemistry
LS	Limestone
MB	Methylene blue
MPN	Most probable number
MOH	Ministry of Health Malaysia
MTZ	Mass transfer zone
NOM	Natural organic matter
NPS	Non-point sources
NSDWQ	National Standard for Drinking Water Quality for Malaysia
NWQS	National Water Quality Standards for Malaysia
PAC	Powdered activated carbon
RBF	Riverbank filtration
SEM	Scanning Electron Microscopy

TDS	Total dissolved solid
TOC	Total organic carbon
WEPA	Water Environment Partnership in Asia
WHO	World Health Organization
WQI	Water Quality Index
$Al_2(SO_4)_3$	Aluminium sulfate
As	Arsenic
Ca^{2+}	Calcium(II) ion
$CaCl_2$	Calcium chloride
$CaCO_3$	Calcium carbonate
Cd	Cadmium
Cd^{3+}	Cadmium(III) ion
Cr	Chromium
Cr^{3+}	Chromium(III) ion
Cu^{2+}	Copper(II) ion
E. coli	Escherichia coli
Fe	Iron
Fe^{3+}	Iron(III) ion
$FeCl_3$	Iron trichloride
Hg	Mercury
$MgCO_3$	Magnesium carbonate
MgO	Magnesium oxide
Mn	Manganese
Ni^{2+}	Nickel(II) ion
NH_3-N	Ammoniacal nitrogen
Pb	Lead

Pb^{2+}	Lead(II) ion
PACl	Poly aluminium chloride
$TiCl_4$	Titanium tetrachloride
Zn^{2+}	Zinc(II) ion

PRESTASI PENJERAP KOMPOSIT - BATU KAPUR/KARBON TERAKTIF/ALGINAT DALAM MERAWAT AIR SUNGAI

ABSTRAK

Pertumbuhan pesat pusat-pusat bandar memerlukan aktiviti ekonomi yang dinamik untuk membangunkan negara. Walaubagaimanapun, ia telah membawa kepada peningkatan pencemaran air sungai yang mengandungi pelbagai bahan pencemar organik dan bukan organik yang sering melebihi had yang dibenarkan standard air minuman. Penggunaan penjerap untuk air sungai telah banyak dijalankan. Namun, tiada data terkini tentang pembangunan penjerap komposit mesra alam sekitar yang diperbuat daripada karbon teraktif (AC) dan batu kapur (LS) serta penggunaan rumpai laut alginat. Dalam kajian ini, prestasi penjerap komposit telah disiasat untuk pra-rawatan air minuman. Penjerap komposit disintesis untuk penjerapan warna dan kekeruhan dari air sungai. Ciri-ciri pendahulu individu dan penjerap komposit untuk rawatan air sungai diselidiki. Pemilihan nisbah campuran terbaik diperiksa dalam kajian berkelompok penjerapan. Kesan dos penjerap dan masa sentuhan diselidiki. Model isoterma dan kinetik untuk penjerap komposit juga ditentukan. Kajian turas dasar tetap disiasat pada bahagian terakhir. Sampel air sungai dikumpulkan dari Sungai Kerian yang terletak di Lubok Buntar, Bandar Baharu, Kedah. Hasilnya menunjukkan, nisbah campuran (AC: LS) 3:7 adalah berkesan dalam menghilangkan lebih daripada 92.6% warna dan 89.7% kekeruhan. Hasilnya juga mendedahkan bahawa kapasiti maksimum penjerapan satu lapisan penjerap komposit untuk warna dan kekeruhan adalah 0.446 PtCo/g dan 5.155 NTU/g, masing-masing. Selain itu, kinetik penjerapan menggambarkan kesesuaian menggunakan model kinetik pseudo-tertib-kedua. Isoterma Freundlich didapati sesuai dengan data penjerapan

keseimbangan. Berdasarkan lengkung terobosan, titik terobosan untuk warna dan kekeruhan kurang dari 6 dan kurang daripada 1 jam, masing-masing. Titik tidak berkesan untuk warna dan kekeruhan ialah masing-masing 20 dan 1223 jam.

PERFORMANCE OF COMPOSITE ADSORBENT–LIMESTONE/ACTIVATED CARBON/ALGINATE IN TREATING RIVER WATER

ABSTRACT

The rapid growth of urban centers required the dynamic economic activities to develop a nation. However, it leads to the increased pollution of river water which contains wide variations of organic and inorganic pollutants that often exceed the permissible limit of drinking water standard. Application of adsorbents for river water has been studied for years. However, there is no data available on the development of composite adsorbent synthesized from activated carbon (AC) and limestone (LS) as the core materials and alginate binder. In this study, the performance of composite adsorbent was investigated for pre-treatment of drinking water. Composite adsorbent was synthesized for the adsorption of color and turbidity from river water. The characteristics of individual precursor and composite adsorbent for the treatment of river water were investigated. The selection of the best mixture ratio was examined in adsorption batch study. The effects of adsorbent dosage and contact time were investigated. The suitable model of isotherms and kinetics for the composite adsorbent were also discovered. The performance of composite adsorbent using fixed-bed column was also investigated at the last part. The river water samples were collected from Kerian River located at Lubok Buntar, Bandar Baharu, Kedah. The results identified, the mixture ratio (AC: LS) of 3:7 was effective in removing color and turbidity over 92.6% and 89.7%, respectively. The results revealed that the maximum monolayer adsorption capacity of composite adsorbent for the adsorption of color and turbidity were 0.446 PtCo/g and 5.155 NTU/g, respectively. Besides, the adsorption kinetics illustrated the suitability of applying the pseudo-second-order kinetic model. The Freundlich isotherm was found well fitted to the equilibrium adsorption data. Based on the breakthrough curve, the breakthrough point for color and turbidity were less than 6 and less than 1 hour, respectively. The ineffective point for color and turbidity were 20 and 1223 hours, respectively.

CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

The status of water quality in Malaysia is not as bad as many other developing countries in the world. However, the water quality of Malaysian inland water (especially rivers) is following a deteriorating trend despite the Environmental Quality Act (EQA) has been enforced in 1974. Besides, according to the Department of Environment (DOE) report, the river water quality in terms of Water Quality Index (WQI) had shown a decrease in 2016. From a total of 477 rivers monitored by DOE, it appears that the percentage of clean rivers have declined remarkably to 47% in 2016 compared to 58% in the previous year. Meanwhile the percentage of polluted rivers had shown an increasing trend from 7% to 10% in 2016 (DOE, 2016).

The availability of good quality raw water is decreasing since the number of polluted rivers are increasing. The quality of the river water is degraded by point sources (sewage, sullage, industrial effluent, etc) and non-point sources pollutants (urban and rural runoff) (Kailasam, 2006). In 2013 in Selangor, seven districts consist of more than one million consumers were affected by water disruptions. It was due to the diesel tanker spillage in Selangor River 10 km from the intake area of a water plant and resulting to the shutdown of four treatment plants. These four plants produce 2.67 billion liters of water daily, meeting 57% of water demand in Selangor, Kuala Lumpur and Putrajaya (The Star, 2013).

Furthermore, extremely dry weather conditions in Malaysia at the beginning of 2014 caused the water level in several dams to decrease to critical levels, thereby reducing the amount of water supplied to approximately 6.7 million people. This situation suggests that existing large-scale dams may not be able to provide adequate water resources, especially during the dry season (Ibrahim, N. et al., 2015).

In the mean time, the rapid growth of population leads to the growing demand of water usage for drinking, irrigation, municipal and industrial development (Afroz et al., 2014). By the year 2020, the water demand is projected to reach 20 billion m^3 as demand is increasing 4% annually. Since rivers contribute 97% of fresh water resource, this is a signal that water supply would have to be treated extensively in future (Kailasam, 2006). Due to that, it is vital to search a suitable method to treat river water.

Numerous works associated with water treatment method have been done in order to treat polluted rivers from various types of pollutants. These methods include centrifugation, filtration, membrane processing, sedimentation, disinfection, crystallization, gravity separation, precipitation, flotation, oxidation, evaporation, coagulation, distillation, solvent extraction, ion exchange, electrolysis, adsorption, electrodialysis, etc (Ali, 2012). Adsorption being the most significant separation technique that has wider application for the removal of heavy metals, organic and inorganic micropollutants from water due to its operation that is easy to handle and large selection of adsorbents available (Mohammed et al., 2014). Thus, in this research study, adsorption process using a new adsorbent was applied to remove physical parameters which are color and turbidity that exist in river water.

1.2 Problem Statement

In the face of climate change and an increasing demand from a growing population, it is compulsory for the country to manage its water resources efficiently to prevent water scarcity. The increasing trend of the polluted rivers percentage in Malaysia also contributes to the shortage problem of the water resources which fully dependent with treated fresh water from the main resources such as river or groundwater. Furthermore, a drastic increase in population and economic activity density make it more difficult to meet the increasing demand for treated and raw water (NST, 2016).

Several methods of water treatment including coagulation (Ramavandi, 2014), advanced oxidation process (Fahmi et al., 2011), ozonation (Akbar, Aziz et al., 2015), adsorption (Agnihotri & Singhal, 2017) and others have been effectively considered for the removal of various pollutants from water. All of them have advantages and disadvantages regarding their cost, environmental impact and productiveness (Chibban et al., 2012). Adsorption is one of the most favorable methods in treating the river water. However, activated carbon (AC) that has been used as an adsorbent was not able to remove some river pollutants. The removal of some pollutants are not good by using AC alone (Benhouria et al., 2015; Odoemelam et al., 2015). The same thing happens to limestone (LS) if it is used as a single adsorbent (Aziz et al., 2001).

Owing to the single use of AC and LS in water treatment is not always very promising, researchers nowadays tend to introduce with composite adsorbent which can give better performance during process treatment. In this study, these two precursors; AC and LS were combined to make an effective composite adsorbent by using alginate for removal of studied parameters (color and turbidity). Alginate is used in water treatment as a binder for composite adsorbent.

There are a quite number of articles on the removal of color and turbidity using adsorption process, but literatures on the color and turbidity removal from river water are not well studied especially with limestone-activated carbon-alginate composite adsorbent. Most of the studies discussed about the removal of heavy metals and dyes from synthetic solution and wastewater. There is also a limited study concerning the batch study and fixed-bed study for the color and turbidity removal from river water that could assist in data analysis. At the same time, some adsorbents do not work well for certain pollutants. Previous studies reported that turbidity was removed by adsorbent materials derived from various plants, gravel and charcoal. Meanwhile, color and dye were removed by composite adsorbent or alginate bead. In this study, we investigated the treatment process of river water for color and turbidity removal simultaneously using limestone-activated carbon-alginate composite adsorbent in batch study and fixed-bed flow studies by applying adsorption process.

1.3 Research Objectives

The research focused to determine the potential use of composite adsorbent as a filter media for pre-treatment of drinking water by using activated carbon, limestone and alginate.

The objectives of this research are:

1. To investigate the characteristics of composite adsorbent; namely activated carbon/limestone/alginate as pre-treatment of drinking water using adsorption process.