TREATMENT OF BAUXITE CONTAMINATED WATER AT SUNGAI PENGORAK USING RIVERBANK FILTRATION SYSTEM (RBF)

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TAN YEE LING

Report submitted in partial fulfillment of the requirements
for the award of the degree of
B. ENG (HONS.) CIVIL ENGINEERING

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LIST OF SYMBOLS

O	Oxygen
Si	Silicon
Fe	Iron
Ca	Calcium
Al_2O_3	Aluminium oxide
$Al(OH)_3$	Aluminium hydroxide
γ-AlO(OH)	Aluminium-oxide-hydroxide
α-AlO(OH)	Aluminium-oxide-hydroxide
Fe_2O_3	Iron oxide
$Al_2Si_2O_5(OH)_4$	Aluminium silicate
TiO_2	Titanium oxide
$CaCO_3/3CaO \cdot Al_2O_3 \cdot 6H_2O$	Calcium compounds
Cd	Cadmium
O_3	Ozone
$CaCO_3$	Calcium carbonate

LIST OF ABBREVIATIONS

RBF	Riverbank filtration
INWQS	Interim National Water Quality Standards
WQI	Water Quality Index
NDWQS	National Drinking Water Quality Standards
DO	Dissolved Oxygen
TDS	Total Dissolved Solids
TSS	Total Suspended Solids
BOD	Biochemical Oxygen Demand
COD	Chemical Oxygen Demand
AN	Ammoniacal Nitrogen
PM 10	Particulate Matter with a mean aerodynamic diameter of 10 μm
DID	Department of Irrigation and Drainage
DOE	Department of Environment
WHO	World Health Organization
MOH	Ministry of Health
RO	Reverse Osmosis
VOCs	Volatile Organic Compounds
NF	Nanofiltration
UV	Ultraviolet
CD	Corona Discharge
MF	Microfiltration
UF	Ultrafiltration
TC	Total Coliforms

FC	Faecal Coliforms
FS	Faecal Streptococci
UMP	Universiti Malaysia Pahang
BS	British Standard
ASTM	American Society for Testing Material
APHA	Federal American Public Health Association
USCS	Unified Soil Classification System

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ABSTRACT

Unregulated and rampant bauxite mining activities in Kuantan, Pahang have been seriously polluted the rivers and oceans nearby Sungai Pengorak and Pantai Pengorak. Commonly, surface water is treated by using conventional water treatment method that involved coagulation, filtration and disinfection process. Due to a higher cost in both construction and chemical usages like alum and chlorine in treating raw water for drinking purpose, therefore, in this study, a more economic and cost-effective alternative water treatment method has been implemented, namely riverbank filtration system (RBF). In this study, a fixed bed column test was conducted to evaluate the treatment efficiency of riverbank in Sungai Pengorak in treating bauxite contaminated water. The riverbank consists of mostly sand and some traces of seashells with a range of size from 7.000mm to 0.063mm. Malaysian Department of Environment Water Quality Index (DOE-WQI) were calculated and classified according to Interim National Water Quality Standards, Malaysia (INWQS). Water Quality Index (WQI) was determined on the basis of nine physico-chemical parameters like pH, colour, turbidity, dissolved oxygen (DO), total dissolved solids (TDS), total suspended solids (TSS), ammoniacal nitrogen (AN), biological oxygen demand (BOD) and chemical oxygen demand (COD). Results shown that, based on WQI and INWQS, the bauxite contaminated water in Sungai Pengorak is classified under Class IV and Class V (i.e. highly polluted) respectively. Data obtained from the WQI for raw water was 49.93. However, the bauxite contaminated water after column filtration test improved significantly to Class I (clean) and 95.65 with respect to WQI. In addition, results from the study also fulfilled the National Drinking Water Quality Standards (NDWQS). This study shown that the riverbank can be effectively and economically been used as a safe alternative to treat bauxite contaminated water.

ABSTRAK

Aktiviti perlombongan bauksit yang tidak terkawal dan berleluasa di Kuantan, Pahang telah serius tercemar sungai-sungai dan lautan berdekatan Sungai Pengorak dan Pantai Pengorak. Biasanya, air permukaan dirawat dengan menggunakan kaedah rawatan air konvensional yang melibatkan pembekuan, penapisan dan pembasmian kuman proses. Oleh kerana kos yang lebih tinggi dalam kedua-dua pembinaan dan kimia kelaziman seperti tawas dan klorin dalam merawat air mentah untuk minum tujuan, oleh itu, dalam kajian ini, kaedah rawatan air yang lebih ekonomi dan kos efektif alternatif telah dilaksanakan, iaitu sistem penapisan tebing sungai (RBF). Dalam kajian ini, ujian ruang katil tetap telah dijalankan untuk menilai keberkesanan rawatan di tebing sungai di Sungai Pengorak dalam merawat air yang tercemar bauksit. tebing sungai ini terdiri daripada kebanyakannya pasir dan beberapa kesan kerang dengan pelbagai saiz dari 7.000mm untuk 0.063mm. Jabatan Malaysia Indeks Kualiti Air Alam Sekitar (DOE-WQI) telah dikira dan dikelaskan mengikut Piawaian Kualiti Air Kebangsaan Interim, Malaysia (INWQS). Indeks Kualiti Air (WQI) ditentukan berdasarkan sembilan parameter fiziko-kimia seperti pH, warna, kekeruhan, oksigen terlarut (DO), jumlah pepejal terlarut (TDS), jumlah pepejal terampai (TSS), nitrogen ammonia (AN), keperluan oksigen biologi (BOD) dan permintaan oksigen kimia (COD). Keputusan menunjukkan bahawa, berdasarkan WQI dan INWQS, air bauksit tercemar di Sungai Pengorak adalah dikelaskan di bawah Kelas IV dan Kelas V (iaitu sangat tercemar) masing-masing. Data yang diperoleh daripada WQI untuk air mentah adalah 49,93. Walau bagaimanapun, air bauksit tercemar selepas ujian penapisan ruangan meningkat dengan ketara kepada Kelas I (bersih) dan 95.65 berkenaan dengan WQI. Di samping itu, hasil daripada kajian itu juga dipenuhi Minum Kebangsaan Piawaian Kualiti Air (NDWQS). Kajian ini menunjukkan bahawa tebing sungai boleh berkesan dan ekonomi telah digunakan sebagai alternatif yang selamat untuk merawat air yang tercemar bauksit.

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF THE STUDY

Aluminium is the most abundant metal and the third most abundant element in the earth's crust (8.3% by weight); it is exceeded in abundance only by oxygen, O (45.5%) and silicon, Si (25.7%), and is approached only by iron, Fe (6.2%) and calcium, Ca (4.6%) (Greenwood & Earnshaw, 2012). The chief ore of aluminium is bauxite. Bauxite is typically a soft (Mohs Hardness: 1-3), white to grey to reddish-brown in colour with a pisolitic structure, clay-like material, earthy luster and a low specific gravity (i.e. 2.0-2.5). The reddish-brown colour of bauxite is due to the presence of iron minerals. Bauxite is a residual type of ore deposit that has been left on the land surface following intense weathering of aluminium-containing rocks and the removal by leaching of silica and other minerals in a wet tropical and subtropical climate (Patterson et al., 1986). As bauxite generally occurs within a few feet of the surface and found superficially in the earth's crust, open-cut methods of mining are usually used for its extraction. Much of this process is highly mechanized. Topsoil is removes and caprock blasted away. Front-end loaders are then used to fill trucks which take the bauxite to a crusher from where the crushed bauxite is transported to a refinery factory for process or a port for shipping out of the region (Meyer et al., 2002).

Bauxite is the ore which is the most commonly used for the production of alumina and aluminium. Therefore, bauxite is the world's main source of aluminium. Major commercial deposits are found in Australia, China, Brazil, Guyana, Ghana, Guinea, Hungary, India, Indonesia, Jamaica and Suriname (Brown et al., 2010; 2015). Bauxite may contain up to 55% aluminium oxide (Al_2O_3) (Beach et al., 2001).The

production of aluminium metal from bauxite ore involves two-stage process, firstly the refining of bauxite to alumina by a wet chemical caustic leach process, namely the Bayer process, and, secondly the electrolytic reduction of alumina to aluminum metal, as known as the Hall-Heroult process (Meyer, 2004). Hence, bauxite, as known as red mud is the waste by-product of the Bayer process to extract pure aluminium oxide from bauxite ores for aluminium metal's production.

Bauxite mining activities have sprung up in Malaysia since late of year 2014, notably in Pahang's state capital of Kuantan, and an area along the east coast facing the South China Sea. According to the Minerals and Geoscience Department, bauxite production in Malaysia more than quadrupled to 962,799 tonnes in 2014 from 208,770 tonnes in 2013. The bauxite mines have been shipping increasing amounts of bauxite for aluminium production to China, filling a gap created when Indonesia banned the ore exports in January 2014 to encourage value-added processing at home (Mineweb, 2015). Malaysia supplied 1.27 million tonnes of bauxite to China in the first nine months of year 2014, 12 times more than the 105,000 tonnes in the same period for year 2013 (Malaysia Kini, 2015a). Besides, in the first 11 months of 2015, Malaysia exported more than 20 million tonnes of bauxite to China, up nearly 700 per cent on the previous year of 2014 (The Straits Times, 2016).

Rapid industrial development has contributed greatly to economic growth but there has been significant cost in environmental degradation and increased public health risks. Unregulated and rampant mining of bauxite activities had spread to the Beserah area in Kuantan, Pahang and exacerbated by the large number of transport lorries carrying the red soil to Kuantan Port for exporting. In this cases, red dust for bauxite mines contaminating the villages when bauxite-laden lorries transport the mineral ore to the port (The Star, 2015b). The wind will blow the red dust everywhere and when it rains, the water washes the dust down the drain, that flow directly into the rivers and finally into the sea. Many rivers and beaches such as Sungai Balok, Pantai Balok, Pantai Batu Hitam, Sungai Pengorak and Pantai Pengorak near Kampung Selamat north of Kuantan have been reported seriously bauxite-contaminated and turning into deep dark-red hue from natural green water (The Star, 2015a). Dangerous traces of heavy metals like arsenic, beryllium, cadmium, chromium, lead, manganese, mercury, nickel,

naturally-occurring radioactive materials such as thorium and uranium besides high levels of aluminium have been detected in this river and sea (The Straits Times, 2015b). Bauxite contaminated water poses a dangerous alarm to marine life by, for instance, clogging the gills of fish and suffocating them.

Surface water besides drinking water contaminated by bauxite is recognized as a major public health in many parts of the world. About one third of the world's population lacks sufficient access to safe drinking water and sanitation to meet their basic needs as well as approximately 900 million people rely on unimproved drinking water supplies (WHO, 2011). Access to good quality and safe water, makes a tremendous difference to our quality of life. As we step into the twenty-first century, it is realized that the trend towards urbanization is posing ever-increasing challenges with respect to water supply. In recent years, to find out cost effective alternative for treating high bauxite contaminant from surface water, many researches have been carried out. Commonly, surface water is treated by using conventional water treatment method that involved coagulation, filtration and disinfections processes (Crittenden et al., 2012). These processes have resulted in a higher cost in both construction and chemical usages like alum and chlorine to control the pathogens in treating raw water for drinking purpose besides causing higher risk to human health (Hammer, 2012).

However, nowadays a more economic and cost-effective alternative water treatment method has been implemented, namely riverbank filtration (RBF). Riverbank filtration describes the process of extracting water from rivers using pumping well located in the adjacent alluvial aquifer whereby surface water is subjected to a combination of physical, chemical and biological processes such as filtration, dilution, sorption and biodegradation, which significantly improve the raw water quality, substituting conventional water treatment method (Jaramillo, 2012). RBF water treatment technology has been widely used in Europe and has been proven effectively improving the source water quality (Ray et al., 2003).

In this study, soil from Sungai Pengorak riverbank was considered and the effectiveness of riverbank soil in improving the water quality parameters and water quality standards of bauxite contaminated water from Sungai Pengorak was investigated