UNIVERSITI PUTRA MALAYSIA

REMOVAL OF NATURAL ORGANIC MATTER FROM SG. SIREH USING LOCAL MANUFACTURED ACTIVATED CARBON

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REMOVAL OF NATURAL ORGANIC MATTER FROM SG. SIREH USING LOCAL MANUFACTURED ACTIVATED CARBON

BY

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Thesis Submitted in Partial Fulfilment of the Requirements for the Degree of Master of Science in the Faculty of Engineering, Universiti Putra Malaysia.

February 1998

ACKNOWLEDGEMENTS

First and foremost, I would like to express my deepest and warmest thanks and appreciation to my chairman, Assoc. Prof. Ir. Ahmad Jusoh and members of the Supervisory Commitee, Assoc. Prof. Ir. Megat Johari Megat Noor, Assoc. Prof. Dr. Mohd Zobir Hussein and Mr. Mohd Pauzi Zakaria for their guidance and advice throughout the duration of this study.

Finally, I would like to record my deepest appreciation to my parents, family members especially Mr. See Boon Yan and my beloved Miss Yap Chiew Lin for their continuous encouragement, moral support and invaluable care in time of troubles and difficulties.

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β	Kinetic coefficients of the external mass transfer
ϕ	The fractional capacity
ν	Viscosity
ΔP	Pressure drop
a	Specific surface area
A, r	Constants (Clark Model)
B	A constant to describe the energy of interaction between the solute and the adsorbent surface
b	An empirical constant with units of inverse concentration
C/D	Amount of unadsorbed solute per unit adsorbent mass
C_B	Allowable effluent concentration
C_e	The equilibrium surface and solution concentrations
C_i	Influent concentration
C_s	Saturation concentration of solute
D	Diffusion coefficient
D_c	Column diameter
D_p	Mean particle diameter
H, L_{bed}	Height of column
K	Constant (Fruendlich Isotherm)
k	Kinetic constant (Adams Bohart Model)
K, A	Empirical constant (Empirical model)
K_F	Constant (Summer Isotherm)
k_{id}	A constant that depicts rate factor
k_{La}	Rate constant of adsorption
M_{AC}	Mass of activated carbon
n	Constant (Fruendlich Isotherm)
N	The maximum number of moles adsorbed per mass adsorbent
N_o	Adsorption capacity (Adams Bohart Model)
q	Units of mass adsorbate/volume or moles adsorbate/mass adsorbent
Q	Volumetric flow rate to contactor
q_t	Amount of adsorbate adsorbed at time t
r_o	Particle radius
t	Time
U	Linear flow rate
V_B	Volume treated to breakthrough
CUR	Carbon Usage Rate
D/DBP	Disinfectants/Disinfection By-Product
DBP	Disinfection By-Product
DOC	Dissolved Organic Carbon

EBCT	Empty Bed Contact Time
GAC	Granular Activated Carbon
HMTZ	Height of Mass Transfer Zone
NOM	Natural Organic Carbon
POC	Particulate Organic Carbon
RMTZ	Rate of Mass Transfer Zone
THM	Trihalomethane
USEPA	United States Environmental Protection Agency

Abstract of thesis submitted to the Senate of Universiti Putra Malaysia in partial fulfilment of the requirements for the degree of Master of Science.

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February 1998

Chairman : Assoc. Prof. Ir. Ahmad Jusoh

Faculty : Faculty of Engineering

The presence of dissolved organic components in potable water supplies is aesthetically undesirable not only because it frequently imparts colour, taste and odour to the treated water, but may also be associated with a variety of problems relating to quality of water that are potentially hazardous to health. Activated carbons have been identified as a suitable and economical method for removal of dissolved organic compounds in drinking water. In this study, activated carbon, KI-6070 and KI-8085, which were provided by KEKWAH INDAH Sdn Bhd were used to remove dissolved organic compounds. The external surface area of activated carbons, KI-6070 and KI-8085 is approximately 277 m^2/g and 547 m^2/g, respectively. Both equilibrium experiments and fixed bed column studies were carried out to study the saturation capacity of the activated carbons. Freundlich and Summers isotherms are found to fit well for all the batch experiments with R-square being approximately 0.9. The saturation capacity of KI-6070 and KI-8085 are approximately 4.042 mg/g and 4.47 mg/g, respectively. The adsorption capacity of KI-8085 was better than that of KI-6070. In the fixed bed column study, generally higher empty bed contact time (EBCT) performed better compared to low EBCT. The maximum cumulative removal of NOM for KI-8085 was 3.0 mg/g, approximately three times higher than KI-6070 which was 1.2 mg/g from the fixed bed column experiment. Clark model was able to simulate the breakthrough limit of the study, while the Adams-Bohart model could only fit up to 50% of the data collected. The study is significant in that it indicates that activated carbon are a possible option for removal of dissolved organic compounds in potable water supply. However, the design of the treatment process using activated carbon in our treatment plants must be carefully evaluated to take into account aesthetic, health and economic considerations.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia untuk memenuhi sebahagian daripada syarat untuk mendapat Ijazah Master Sains.

PENYINGKIRAN BAHAN ORGANIK SEMULAJADI DARIPADA SG. SIREH DENGAN MENGGUNAKAN KARBON TERAKTIF BUATAN TEMPATAN

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Kehadiran bahan organik terlarut dalam bekalan air adalah tidak diingini dari segi estetik bukan sahaja kerana ianya sering meninggalkan warna, rasa dan bau kepada air rawatan, malahan juga ia mungkin berkaitan dengan pelbagai masalah berhubungan dengan kualiti air yang berpotensi mengancam kesihatan. Karbon teraktif telah diketahui sebagai satu cara yang sesuai dan ekonomi untuk menyingkirkan bahan organik terlarut dalam air minuman. Dalam kajian ini, karbon teraktif KI-6070 dan KI-8085, yang dibekalkan oleh KEKWAH INDAH Sdn Bhd digunakan untuk menyingkirkan bahan organik terlarut. Luas permukaan luaran bagi karbon teraktif, KI-6070 dan KI-8085 adalah dianggarkan 277 m^2/g dan 547 m^2/g, masing-masingnya. Kedua-dua ujian keseimbangan dan turus media tetap dijalankan untuk mengaji kapasiti penjerapan karbon teraktif tersebut. Isoterm Freundlich dan Summers didapati menepati semua ujian

sekelompok dengan anggaran R^2 berada dalam 0.9. Kapasiti tepuan KI-6070 dan KI-8085 adalah disekitar 4.042 mg/g dan 4.47 mg/g, masing-masingnya. Kapasiti penjerapan bagi KI-8085 adalah lebih baik daripada KI-6070. Dalam ujian turus media tetap, didapati secara umumnya masa sentuhan media yang panjang akan menghasilkan prestasi yang lebih baik berbanding dengan masa sentuhan yang singkat. Kumulatif maksimum penyingkiran bahan terlarut bagi ujian turus adalah disekitar 3.0 mg/g bagi KI-8085, dianggarkan tiga kali lebih tinggi daripada KI-6070 yang bernilai 1.2 mg/g. Model Clark berkebolehan untuk meramalkan dengan tepat tahap penembusan sepanjang ujian, manakala Model Adams-Bohart hanya menepati ramalan sebanyak 50% sahaja. Kajian ini bererti dalam menunjukkan bahawa karbon teraktif adalah satu cara berkemungkinan untuk menyingkirkan bahan organik terlarut dalam bekalan air. Bagaimanapun, reka bentuk proses rawatan yang menggunakan karbon teraktif dalam loji perawatan kita mestilah dinilai teliti dengan mengambil kira keindahan (estetik), kesihatan dan ekonomi.

CHAPTER I

INTRODUCTION

Global Fresh Water Issues

Water is indispensable for human health and welfare. Water is a necessary commodity in household and municipal activities, and a critical factor in agricultural and industrial production. Its presence or absence can mean life or death, prosperity or poverty while access to it and control over it can lead to political conflict, or even war.

The world is approaching a breaking point in terms of socioeconomic development and its relation to water resources. Rapid population growth in the tropic and subtropics, particularly in regions with a dry climate is likely to cause increasing water scarcity. In a few decades, if water demand continues unrestrained, it will outstrip the amount that can be sustainably provided in many areas. Conventional ways of handling solid waste and wastewater are also unsustainable. Urban wastewater volume, growing at the same pace as water demand. In many areas where water can no longer be treated safely and effectively with conventional technologies such as coagulation, flocculation, sedimentation, filtration and disinfection processes.

Early in the nineteenth century Samuel Taylor Coleride in his classical poem " The Rime of the Ancient Mariner, " effectively described the principal characteristic of the earth's water resources when he wrote, " Water, water, everywhere, not any drop to drink." Ninety percent of the world's water resources constitutes salt water - unsuitable for drinking or growing crops. The remaining 3% is fresh water, comprising a total volume of about 35 million km^3. If this water were spread out evenly over the surface of the earth it would make a layer 70 m thick. Yet almost all of this fresh water is effectively locked away in the ice caps of Antarctica and Greenland and in deep underground aquifers, which remain technologically and economically beyond our reach. Less than 100,000 km^3- just 0.3% of the total fresh water reserves on earth, is found in the rivers and lakes that constitute the bulk of our usable supply (Gleik, 1994).

River Water Quality and Problems

The problem of water quality degradation in rivers and streams is not new in Malaysia and has been recognised as a problem even before the establishment of Environmental Quality Act of 1974. Agricultural, industrial and municipal activities are the major polluters as well as main consumers of the water resources. The deterioration and presence of pollutants in rivers and streams, caused by erosion and discharge of domestic and industrial wastes into the rivers can be detrimental to human health if the contaminated water is not appropriately processed prior to human consumption (Ong and Debbie, 1993).

In this era of industrialization and economic development, water and raw water pollution or contamination is inevitable. However, what is important is that water is treated. Water treatment is necessary for the removal of particulates and chemical pollutants, prevention of communicable disease transmission and improvement of the aesthetic quality of water for consumption. To achieve these objectives of water treatment, the use of chemicals cannot be avoided (Ong and Debbie, 1993).

In Malaysia, chlorine is the disinfectant of choice although some utilities use chloramine. Except for smaller plants, most of the utilities use chlorine gas for disinfection. The proper use of chlorine in water is beneficial although chlorine gas by itself is hazardous in nature.

Epidemiological studies carried out in the United States suggest a weak-to-moderate association between water chlorination and colon cancer.

These studies also showed that drinking water with greater than average amounts of chlorinated water over a span of 40 years can result in bladder cancer (Ong and Debbie, 1993).

Most odour and taste problems occur at the water treatment stage and are linked to chlorination. Chlorine itself has a distinctive odour with a reported taste threshold of 0.16 mg/l at pH 7 and 0.45 mg/l at pH 9. Although a slight chlorine odour is generally acceptable, excessive concentrations of chlorine can make water unpalatable and objectionable (Gray, 1994).

In raw water treatment supplies, odour is mainly contributed by organic substances of natural origin, especially from algae and/or decaying vegetation. Odour is formed when algae die (Gray, 1994). Besides odour and taste, colour is another factor that requires particular consideration. Coloured water is not aesthetically acceptable to the general public (Peavy *et al.*, 1985).

Generally, coloured water is related to the properties and behaviour of the soil condition. Reddish colours often indicate soils that are highly weathered with large oxidized iron content; grayish colours may be diagnostic of soils with permanently high and stagnant water tables. Mottled soils with spots of different colours in humid regions may have fluctuating water tables (Olson, 1981). Colours formed by inorganic substances can be removed by physical-chemical processes but this is not the case with organically formed colours. Hence, it is ultimately important to find a solution to remove natural organic matter (NOM) in raw water treatment. So as to provide consumers with better and safer water for consumption.

The Sg. Sireh Water Treatment Plant

The Sg. Sireh Water Treatment Plant is located at Parit Satu, Sungai Sireh, Tg. Karang, Selangor Darul Ehsan. It was built in 1986 and started operations in 1988. The treatment plant can treat 6 million gallons of water per day. Treated water is distributed to the households in the Tg. Karang and Sekinchan areas.

This plant is operated and maintained by Taliwork Consortium Sdn. Bhd. The raw water quality of the plant is affected by high dissolved organics and colour problems. Raw water quality problems become worse especially during the raining season. Chemical oxygen demand (COD) and dissolved organic carbon (DOC) values can reach as high as 300 mg/l and 50 mg/l, respectively. The main contributing factor to these problems is the location of the plant in a swampy area that is rich in organic matter. During the raining season, the surface runoff flushes off the decayed organic matter together with other organic debris into the river.

Conventional treatment processes are not sufficiently efficient to remove DOC in the intake point. High organic matter requires greater dosage of chlorination in the disinfection stage and also increases trihalomethanes (THMs) formation in the treated water. This indirectly increases the processing cost of water. Higher THM concentrations in the water poses a health hazard to consumers.

Solutions

Recently activated carbon has been identified as the most suitable and economical way for the removal of selected organic compounds. A thorough understanding of the adsorption and diffusion qualities of these humic substances is required, as macromolecular organic matter is ubiquitous in the aqueous environment (Summers and Roberts, 1988a).

In a study carried out by USEPA (Ong and Debbie, 1993) on potential cancer risk reduction by using granular activated carbon (GAC), it was found that GAC can remove more than 25% of the 50 chemicals analyzed with a removal efficiency of greater than 90%. Using these data on removal efficiencies, the amount of risk reduction was calculated. Table 1 shows the risk reductions achieved for certain chemicals with the use of GAC.