REGENERATION POTENTIAL OF BENTONITE BASED THIN COATED ADSORBENT

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REGENERATION POTENTIAL OF BENTONITE BASED THIN COATED ADSORBENT

by

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LIST OF SYMBOLS

q_e	Quantity of dye (mg/g) adsorbed/desorbed at equilibrium
Q_m	Maximum adsorption capacity of adsorbent (mg/g)
K_L	Constant of Langmuir isotherm (L/mg)
Ce	Equilibrium concentration of dye (mg/L)
K_F	Freundlich isotherm constant [(mg/g) $(L/mg)^{1/n}$
1/n	Adsorption intensity or factor of heterogeneity
b_{RP}	Redlich-Peterson isotherm constant [L/mg]
α_R	Redlich-Peterson isotherm exponent
Ks	Sips isotherm model constant (L/g)
αs	Sips isotherm model exponent
β_S	Sips isotherm model constant (L/mg)
q_t	Quantity of adsorbate adsorbed (mg/g) at time t
k_1	Rate constant of pseudo first order (1/h)
k_2	Rate constant of pseudo second order (1/h)
ΔH	Enthalpy
ΔS	Entropy
ΔG	Gibb’s free energy
E_a	Activation energy
R	Universal gas constant
A	Arrhenius factor
R^2	Correlation coefficient

LIST OF ABBREVIATIONS

AC	Activated carbon
BET	Brunauer, Emmett and Teller
DTA	Differential thermal analysis
EDX	Energy dispersive X-ray
FTIR	Fourier transform infrared
MB	Methylene blue
PSD	Particle size distribution
PS1	Pseudo first order model
PS2	Pseudo second order model
R-P	Redlich-Peterson
RMSE	Root mean square error
SEM	Scanning electron microscopy
TGA	Thermogravimetric analysis

POTENSI PEMULIHAN LAPISAN PENJERAP NIPIS BERASASKAN BENTONIT

ABSTRAK

Penjerapan adalah salah satu kaedah yang digunakan secara meluas untuk merawat air sisa kerana ia adalah kos efektif, mesra alam dan sangat cekap. Lapisan penjerap berasaskan bentonit telah diperkenalkan untuk mengatasi masalah yang berkaitan penggunaan penjerap dalam bentuk pelet, granul, serbuk atau bentuk zarah lain, Kapasiti penjerapannya meningkat kerana nisbah permukaan kepada berat permukaan meningkatkan. Penting untuk pemulihan semula penjerap sebelum dibuang ke persekitaran. Oleh itu, kajian ini memberi tumpuan kepada kebolehsanaan pemulihan semula lapisan penjerap berasaskan bentonit menggunakan tiga kaedah yang berbeza; kebolehsanaan pemulihan secara kimia, kebolehsanaan pemulihan secara terma dan gabungan antara terma dan kimia. Kebolehsanaan pemulihan secara kimia didapati tidak sesuai dengan kecekapan penyahjerapan MB hanya sebanyak 22 % menggunakan etanol. Sebaliknya, kesan terma boleh melonggarkan ikatan antara bahan jerap dan penjerap, tetapi tidak dapat memecahkan sepenuhnya ikatan antara penjerap dan MB pada suhu 160 ^{o}C. Gabungan kaedah kebolehsanaan pemulihan terma dan kimia berkesan menghilangkan MB dengan kecekapan penyahjerapan sebanyak 74 % menggunakan HCl selepas pemanasan pada suhu 160 ^{o}C untuk kepekatan pewarna awal sebanyak 50 ppm. Juga, hasil penjerapan / penyahjerapan MB menggunakan lapisan penjerap berjaya digunakan sehingga 7 kali kitaran. Pencirian *Paintosorp*^{TM} sebelum dan sesudah penyahjerapan pewarna telah dinilai menggunakan analisis TGA / DTA, SEM, EDX, BET, PSD dan FTIR. Kajian penyahjerapan MB secara berkelompok menunjukkan isoterma model Sips dan Freundlich adalah sesuai dan menunjukkan penyahjerapan MB berlaku secara banyak lapisan di permukaan

lapisan penjerap. Kinetik penyahjerapan sesuai dengan model pseudo-tertib kedua dan menunjukkan mekanisma penyahjerapan berlaku kerana kecerunan kepekatan, kelarutan dan penyebaran bahan pewarna MB di lapisan penjerap.

REGENERATION POTENTIAL OF BENTONITE BASED THIN COATED ADSORBENT

ABSTRACT

Adsorption is one of the widely used method for wastewater treatment since it is cost-effective, eco-friendly and highly efficient in nature. Bentonite based adsorbent coating was introduced to overcome the problem associated with the use of adsorbents in pellet, beads, powder, or other particle forms. Its adsorption capacity increases due to increase in surface area/weight ratio. It is important to regenerate adsorbent before it is disposed into environment. Therefore, this study is focused on regeneration of bentonite-based coating using three different methods; chemical regeneration, thermal regeneration and combination of thermal and chemical (thermo-chem) regeneration. Chemical regeneration was not found to be suitable for the regeneration of bentonite adsorbent coating with 22% desorption efficiency of MB using ethanol. Rather, thermal effect can loosen the bonds between adsorbate and adsorbent, but unable to completely break the bond between MB and adsorbent coating at 160^{o}C. The thermo-chem method effectively desorbed MB with desorption efficiency of 74 % using HCl after heating adsorbent coating at 160 ^{o}C for initial dye concentration of 50 ppm. Also, regeneration study results confirm successive adsorption/desorption of MB on adsorbent coating even after 7th cycle. The characterization of *Paintosorp*^{TM} before and after desorption of dye has been performed using TGA/DTA, SEM, EDX, BET, PSD and FTIR analysis. Batch desorption study of MB results Sips and Freundlich isotherm model are best fitting which shows that desorption of MB occurs from multilayer adsorbed MB on adsorbent coating. However, kinetic model best fitting with pseudo second order model and confirms that desorption mechanism is due to concentration gradient, solubility and diffusivity of MB.

CHAPTER 1

INTRODUCTION

1.1. Water pollution

We are living in challenging times where there have been substantial changes in the climate pattern of the planet due to excessive and irresponsible industrial and individual activities. The planet is trying to cope up with these unwanted intrusions by mankind with its own healing mechanisms. But the scientists and researchers are convinced that if something concrete and substantial is not done to slow up the disturbance with nature`s ecology, the life on the planet in general and humans in particular will not survive long, the effect of which has already been started showing up. Water pollutions is one of the major causes for the death of millions of aquatic lives. Some species such as turtle, whales, hector's dolphins are already extinct while many are on the verge of extinction. More than one third of people in world are affecting the lack of improved sanitation and safe drinking water (Roshni, 2018). According to World health organization, half of population of world will be affected by lack of water until 2025 (WHO, 2018). Water has the property of cleansing itself from pollutant by diluting the pollutant to a point where they are not in harmful concentration (Soheila, 2012).

The exposure to pathogens or to chemical toxicant via food chain is a threat for humans and animals (Dwivedi *et al.,* 2018). Consumption of such contaminated water responsible for estimated annual burden of 2 million diarrheal deaths (UNESCO, 2017). The water in oceans is 97% of total earth water, 2 % of the remaining is fresh water. 67 percent of the fresh water is trapped in glaciers and icebergs. Remaining 33% of the 3% is divided among surface water, groundwater and other sub sources is available for human consumption (Jayaswal *et al*., 2017). Although there is enough drinking water, at present, for every living creature on Earth, some of the sources are ill managed while some others are prone to pollution.

Industrial effluent discharge is the major source of water pollution. Industries like textile industries consumes large amount of water and generate almost 90% of wastewater (Mondal *et al*., 2017a). The textile industries using different types of dyes for colouring of fabric in large numbers which are disposed in water bodies. The textile dyeing contributes to 17-20% of industrial water pollution as per the reports of World Bank (Kant, 2012). Pollutants mainly consist of 72 types of toxic chemical elements, 30 of which cannot be removed from water (Liu *et al*., 2018b). Thus, huge amount of wastes produced by textile manufacturers can have serious environmental impact on quality of water (Sandins and Peters, 2018).

Governments of various nations have imposed many regulations and laws on the industries, but these laws are regularly violated, and their implementation is subject to the abilities of the governments to check such violations. Industries, on the other hand need a cheap and sustainable solution for treating the waste water effluent before discharge to the water bodies.

1.2. Textile industries in Malaysia

Textile industry in Malaysia has emerged as one of the promising industries from past to future due to its great demand in the world market. Malaysia, as one of the developing countries has strengthened its position in the textile and clothing industry. The Malaysian's textile major export markets and apparel are United States, Canada, Turkey and European Union. It was reported that Malaysia is the eleventh largest exporter in 2017 which is 2.6% of Malaysia's total export of manufactured goods (MIDA, 2018). The total investment that had been done in year 2017 for 12 projects of textile products in Malaysia is RM 428.8 million in which 25.8% are domestic investment and 75.2% is international investment . These projects generates total 1850 employment opportunities for the position of engineers, quality controllers and high skilled technicians (MIDA, 2018). Therefore, due to large amount of textile produced, it indicates that large amount of wastewater containing pollutants is generated. The percentage of textile effluent that contributes to water pollution by different states in Malaysia are shown in Figure 1.1. Johor (28.6%) and Pulau Pinang (28.2%) are highest sources of water pollution among all states of Malaysia. The effluent of textile industry consists of colour, high chemical oxygen demand, suspended solid and toxicity. Hence, the effluent should be treated properly to remove the colour and reduce COD level to meet Malaysia Environmental Quality Act (1974) for industrial effluent standard discharge limit.

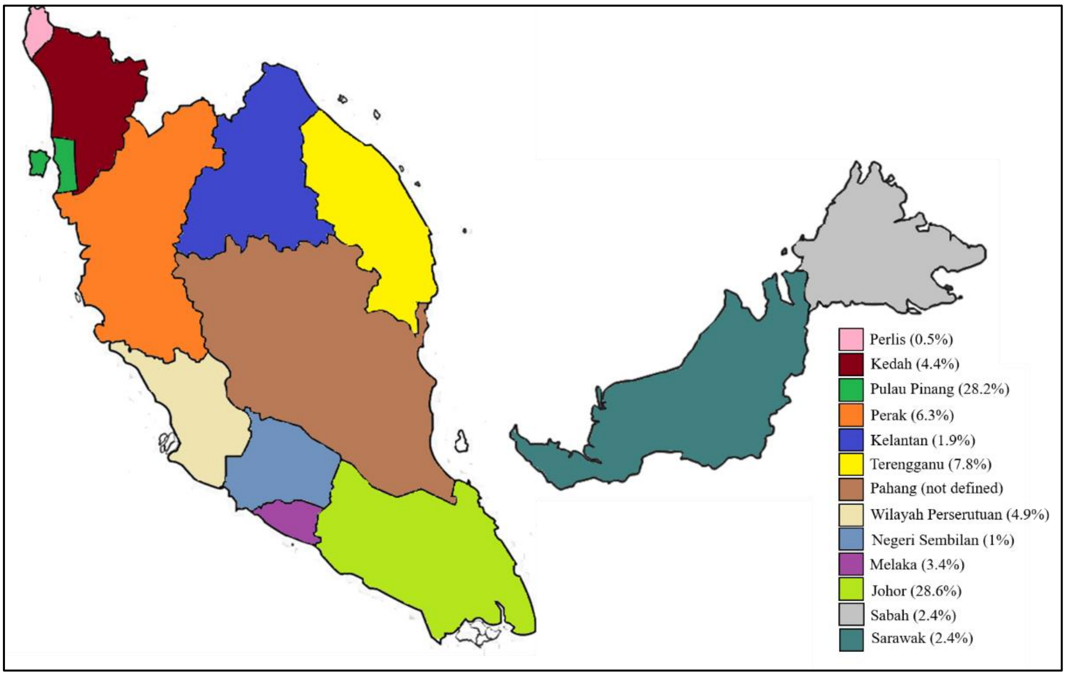

Figure 1.1. The percentage of textile effluent disposal that contribute to water pollution for various states in Malaysia (Pang and Abdullah, 2013)

1.3. Effluents from textile industries

Textiles industry has the major share in the worlds water footprints and dyeing is the biggest problem both in terms of water use and pollution. They produce large amount of effluents start from washing off to bleaching, dyeing, and washing of finishing products and are discharged into environment. Effluents such as dyes are 100,000 commercially available and $7x10^5$ tons of dyestuff produced annually worldwide (Rahman *et al.,* 2018). In addition, it is reported that the dyeing process is inefficient which results in loss of 200,000 tons of dyes every year to effluents during the dyeing and finishing operations (Chequer *et al.*, 2013). Also, dyes cannot be biodegraded because of their complex structure are synthetic in nature (Rahman *et al.*, 2018). Therefore, long term exposure such dyes can cause health hazards and should be treated with care.

The inhalation of dye particles causing most common hazard that is respiratory problems. The organic dyes may produce carcinogenic aromatic amines if the effluent is not treated completely. Besides that, the highly visible colour will also block the sunlight through the water and interrupt photosynthesis process of plant affecting the life in aquatic ecosystem. In addition, dyes cause micro toxicity to aquatic life (Saini, 2018). Dyes are in very small amount as a pollutant in water but still they greatly affect the visibility of water. It also effect the aesthetic quality and transparency of lakes and rivers and adversely affect the aquatic environment (Hema and Suresha, 2015). Therefore, it is mandatory to treat the dye containing water before discharging into environment or water bodies. Several methods were used for this purpose.

1.4. Adsorption and desorption of effluents

Dyes from wastewater can be removed by physicochemical, chemical and biological methods. Due to the non-biodegradable nature of most of the dyes cannot be removed by biological and chemical techniques. Nowadays, few methods are being used by industries for the removal of dyes from wastewater such as adsorption, coagulation flocculation, ion exchange, chemical oxidation, catalytic oxidation,