Enhancing Adsorption Capacity of Bentonite for Dye Removal: Physiochemical Modification and Characterization

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABBREVIATIONS

AA	Acid Activation
ATA	Acid and Thermal Activation
BET	Braunneur – Emmet – Teller
CR	Congo Red
FTIR	Fourier Transform Infra Red Spectroscopy
RB	Raw Bentonite
SEM	Scanning Electron Microscopy
TA	Thermal Activation

ABSTRACT

Bentonite, enormously abundant natural clay, has been considered as a potential absorbent for removing pollutants from water and wastewater. Nonetheless, the effective application of bentonite for water treatment is limited due to small surface area and presence of net negative surface charge, leading to its low adsorption capacity. The net negative charge on the surface of bentonite is the prime factor that restricts the use of bentonite for the adsorption of cationic dyes. As a result, the focus of this research was directed towards the modification of the physical structure and the chemical properties of bentonite to maximize its adsorption capacity. To achieve this aim, the research study was carried out by two stages; (1) modification of Australian raw bentonite and (2) characterization and optimization of adsorption performance and kinetics of the modified Australian bentonite for removing recalcitrant organic dye Congo red (CR).

The modification of raw bentonite was carried out by three physiochemical methods; (1) thermal activation (TA), (2) acid activation (AA) and (3) combined acid and thermal activation (ATA). The characterization of the physiochemically modified bentonite clays was carried out by Braunneur – Emmet – Teller (BET) method for surface area, scanning electron microscopy (SEM) for morphology and Fourier transformation infrared (FTIR) spectroscopy for the determination of the effect of acid attack. The increase in surface area of the modified bentonite was recorded as 20%, 65% and 69.45% by TA, AA and ATA, respectively. The microscopic images obtained through SEM showed that the structure of the modified clay has become more porous, offering additional adsorption sites enhancing the surface properties of bentonite.

The modified bentonites by TA, AA and ATA were examined for their performance as an adsorbent for the CR removal. The effect of key operational parameters, such as contact time, initial dye concentration, adsorbent dosage, pH and temperature was experimentally studied. The CR adsorption increased with an increase in contact time. A CR removal of 96.65%, 92.75% and 91.62% was obtained within first 2h using the bentonite modified by ATA, AA and TA, respectively. Near 100% of dye removal was achieved in 22h. The adsorption capability of bentonite increased steadily with an increase in initial dye concentration. The pH changes appeared to have insignificant impact on the CR adsorption. The adsorption capacity decreased slightly with an increase in temperature, suggesting favorable adsorption at low temperatures for all modified bentonites. The evaluation of thermodynamic parameters revealed that adsorption process is spontaneous and exothermic.

The equilibrium data was analyzed using Langmuir and Freundlich adsorption isotherms. Freundlich isotherm provided a better fit to the data. Results from kinetic study revealed that the CR adsorption on all modified bentonites occurs in multilayers, and does not form a monolayer. It was approved by a steady increase in CR adsorption with the increase in initial dye concentration. Further to understand the adsorption kinetics the adsorption data were analyzed by pseudo first-order and pseudo second-order kinetics. The results revealed that adsorption follows pseudo second-order kinetics. The mechanism of adsorption was interpreted from the intraparticle diffusion model and it was found that apart from intraparticle diffusion there are other factors that control the adsorption.

The results from this study suggest that a combination of thermal and acidification, as referred ATA in this study be an effective method to improve adsorption capacity of the bentonite. The bentonite modified by ATA provides the maximum surface area and adsorption capacity and can be successfully employed for the removal of dyes from wastewater. Bentonite is abundant natural adsorbent. Therefore, application of the simple and low cost modification techniques employed in this study can make the bentonite as cost-effective adsorbent for removal of many organic and inorganic pollutants.

DECLARATION

This work contains no material which has been accepted for the award of any other degree or diploma in any university or other tertiary institution and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due references has been made in the text.

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