

The Influence of Bentonite on the Removal of Methyl Violet Dye

S. Ghanbarnezhad^{1,2}, L. Sharifi¹, S. H. Mirhosseini¹, V. Khani^{1,3} and S. H. Zare⁴

¹Academic Center for Education, Culture and Research, Yazd Branch, Iran

²Department of Material Science Engineering, Science and Research branch
Islamic Azad University, Tehran, Iran

³Departments of Materials Science and Engineering, Tarbiat Modares University,
Tehran, Iran

⁴Departments of Chemical Science, Islamic Azad University, Yazd, Iran

S.Ghanbarnezhad@yahoo.com, Sharifi.Leila.jd@gmail.com,
mirhosseini.jd@gmail.com, vajihe.khani@gmail.com, Sh.Zare@yahoo.com

Abstract

Removal of dyes which are toxic in nature from industrial wastewaters is currently of great interest. For this purpose, the use of Bentonite for the removal of methyl violet dye from aqueous solutions at different contact times, pH and temperature was investigated. Bentonite has a high potential to adsorb reactive dyes from aqueous solutions according to TEM image. The extent of dye removal increased with increasing adsorbent concentration, contact time, pH and temperature. Increasing the temperature shows increasing the rate of diffusion of the adsorbate molecules across the external boundary layer and in the internal pores of the adsorbent particle. The kinetics of the adsorption process was tested for the pseudo-first order and pseudo-second order reaction models. The rate constant of adsorption was obtained for the pseudo-second order kinetic model. The adsorption capacity of the Bentonite is comparable to the other available adsorbents, and it is quite cheaper.

Keywords: Aqueous, adsorbent, bentonite, methyl violet, wastewater

1. Introduction

Colored dye wastewater occurs as a direct result of the production of the dye and also as a consequence of its use in the textile and other industries. Colored effluents and dyes can cause toxic problems in several type of receiving media and can have acute or chronic effects on exposed organisms [1, 2]. There are many processes available for treatment of dyes: chemical oxidation, flotation, adsorption, electrolysis, chemical coagulation, photocatalysis and biodegradation. Among all these, adsorption has been found to be an efficient method for the removal of dyes from aqueous solutions because it produces high quality treated effluent and also allows kinetic and equilibrium measurements without any highly sophisticated instruments [4, 5]. Different adsorbents have been used for removal of various materials from aqueous solutions, such as dyes, metal ions and other organic materials. These include perlite [1–6], activated carbon [7–11], bentonite [12], silica gels [13], flyash [14–16], lignite [17], peat [18], silica [19], etc., In order to minimize processing costs for these effluents, recent investigations have focused on the use of cheaper and easily obtainable low cost unconventional adsorbents. Bentonite, which form an important group of clay minerals, and because of their structural morphology currently used in a number of different applications such as many industrial, catalytic and environmental applications, most of which are similar to those of the more traditional clays. There are different types of bentonite, each named after the respective dominant element, such as potassium (K), sodium (Na), calcium (Ca), and aluminium (Al). Experts debate a number of classified problems with the classification of bentonite clays.

Bentonite usually forms from weathering of volcanic ash, most often in the presence of water. However, the term bentonite, as well as similar clay called tonstein, has been used to describe clay beds of uncertain origin. For industrial purposes, two main classes of bentonite exist: sodium and calcium bentonite. In stratigraphy and tephrochronology, completely devitrified (weathered volcanic glass) ash-fall beds are commonly referred to as K-bentonites when the dominant clay species is illite. Other common clay species, and sometimes dominant, are montmorillonite and kaolinite. Kaolinite-dominated clays are commonly referred to as tonsteins and are typically associated with coal [12, 20]. The main uses of bentonite are for drilling mud, binder (*e.g.*, foundry-sand bond, iron ore pelletizer), purifier, absorbent (*e.e.* pet litter), and as a groundwater barrier. As of around 1990, almost half of the US production of bentonite was used for drilling mud [20, 21].

So, the present study deals with the adsorption abilities for removal of Methyl violet dye from wastewater. The influence of several parameters such as pH, temperature and time was explored.

2. Experimental

Bentonite, is a clay mineral with a unit cell formula $(\text{Na,Ca})_{0.33}(\text{Al,Mg})_2(\text{Si}_4\text{O}_{10})(\text{OH})_2 \cdot n\text{H}_2\text{O}$ [12] used as an adsorbent heated before using for surface activation. The surface of was characterized by transition electron microscopy which is shown in Fig. 1, TEM micrograph of it, it is observed; that had an irregular, heterogenous and porous surface, which indicated high surface areas. Bentonit has several adsorption applications due to its channel structure. The presence and concentration of surface functional groups play an important role in the absorption capacity and the removal mechanism of the adsorbates. The structural form of Methyl violet ($\text{C}_{24}\text{H}_{28}\text{N}_3\text{Cl}$) [407.5 g/mol and $\lambda_{\text{max}}=594$] dye is given in Figure 2. The concentrate of it in 250 ml suspension was 25 ml (10^{-5}). A 0.1 mg bentonit absorbent was used to affect in solution at various loading pH ranging from 1 to 6, temperature ~ 10 to 80 °C as well as at different contact times.

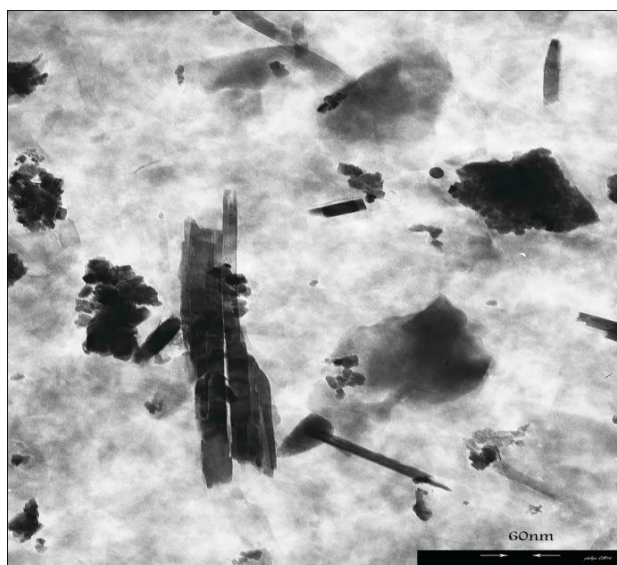


Figure 1. Transition Electron Microscopy Image of Bentonite

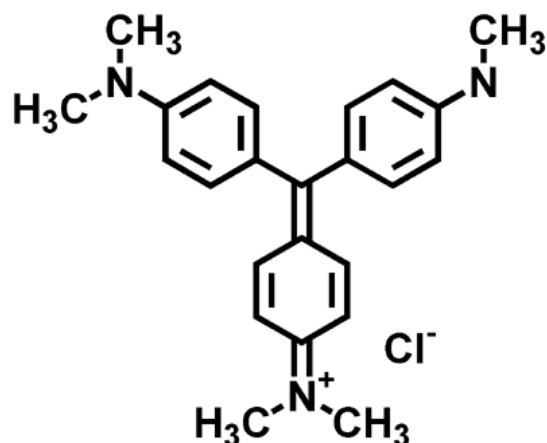


Figure 2. Methyl Violet Structure

3. Results and Discussion

3.1. The Effect of PH on Adsorption

The pH of a solution is of significance for its effect on the adsorbent, as well as on the adsorbate. Both adsorbent and adsorbate may have functional groups that can be protonated or deprotonated to produce different surface charges in solutions at different pH. This results in the electrostatic attraction or repulsion between charged adsorbates and adsorbents [22]. All adsorption experiments were investigated at the constant temperature 25 °C and pH 1 to 6 in solutions. The effect of pH was observed by studying the adsorption of dye over a pH range. The pH of the solution was adjusted with 0.1MNaOH or HCl solution. Figure 3, demonstrates that the adsorption increases with increasing pH because of the electrostatic attraction between the chromophore groups of dye and the negatively charged bentonite surface. At lower pH value more protons will be available to protonate the adsorbent surface, thereby increasing the electrostatic attractions between negatively charged dye anions and positively charged adsorption sites and causing an increase in the dye adsorption. As the initial pH of the solution increases, the number of negatively charged sites increases. A negatively charged surface site on the adsorbent does not favour the adsorption of dye anions due to the electrostatic repulsion.

3.2. The Effect of Temperature on Adsorption

The temperature has two major effects on the adsorption process. Increasing the temperature is known to increase the rate of diffusion of the adsorbate molecules across the external boundary layer and in the internal pores of the adsorbent particle, owing to the decrease in the viscosity of the solution. In addition, changing the temperature will change the equilibrium capacity of the adsorbent for a particular adsorbate. Figure 4: shows the effect of temperature on adsorption on 30 ml methyl violet solution with 0.1 mg bentonit. It is observed; that the adsorption increases with increasing temperature. This may be a result of increase in the mobility of the dye with increasing temperature and increasing temperature may also produce a swelling effect within the internal structure of the adsorbents enabling large dye to penetrate further.

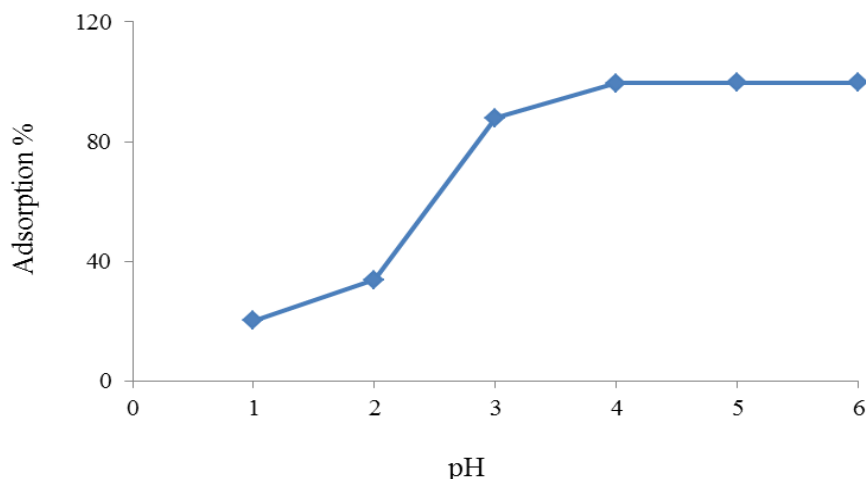


Figure 3. The Effect of pH on Adsorption at 25 °C and 0.1 mg Bentonite on 30 ml Methyl Violet Solution

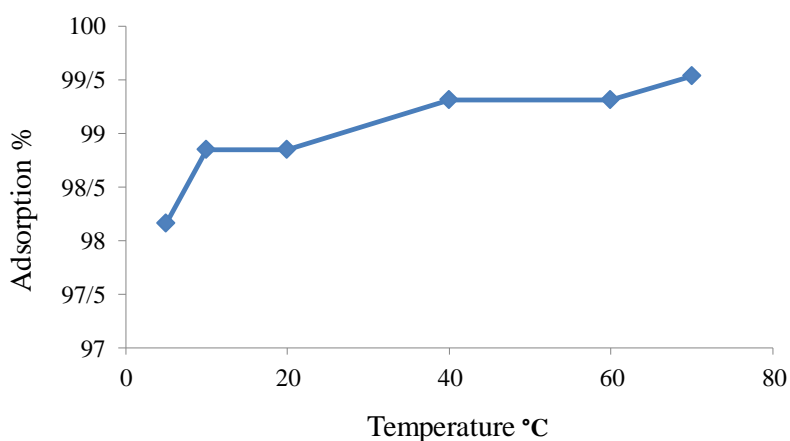


Figure 4. The Effect of Temperature on Adsorption on 30 ml Methyl Violet Solution with 0.1 mg Bentonite

3.3. The Effect of Different Contact Time on Adsorption

A series of experiments was performed to optimize the adsorption time at an initial dye concentration of 10^{-5} mol/L. The effect of contact time on the adsorption rate of dye is presented in Figure 5, the effect of contact time for the removal methyl violet dye by bentonite showed rapid adsorption of dye by increasing the contact time. This was caused by strong attractive forces between the dye molecules and the adsorbent; fast diffusion onto the external surface was followed by fast pore diffusion into the intra particle matrix to attain rapid equilibrium.

3.4. The Effect of Various Loading Adsorbent on Adsorption

For this study, pH~5, temperature~ 25 °C and time~ 45 min, choose with different amount of adsorbent ranging from 0.05 to 0.6 mg to 30 ml methyl violet solution at an initial dye concentration of 10^{-5} mol/L which is shown in Figure 6, as expected by increasing adsorbent the adsorption increased. It has been stated that increasing in the ionic strength of the solution increases adsorption at pH values below the isoelectrical

point and decrease adsorption at pH values above the isoelectrical point. A cause of increasing of adsorption in increasing ionic strength is that increasing in the ionic strength increases the positive charge of the surface below the isoelectrical point, resulting in greater attraction of anions, and increases the negative charge on the surface above the isoelectrical point, resulting in greater repulsion of anions.

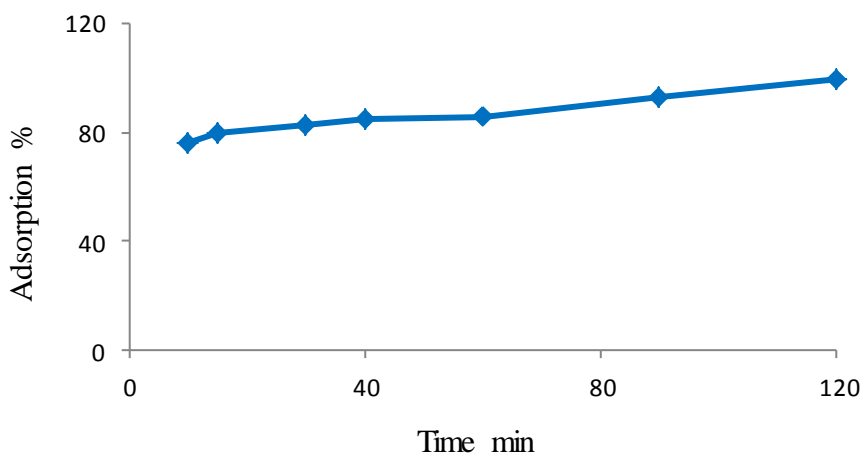


Figure 5. The Effect of Contact Time on Adsorption Rate on 30 ml Methyl Violet Solution with 0.1 mg Bentonite

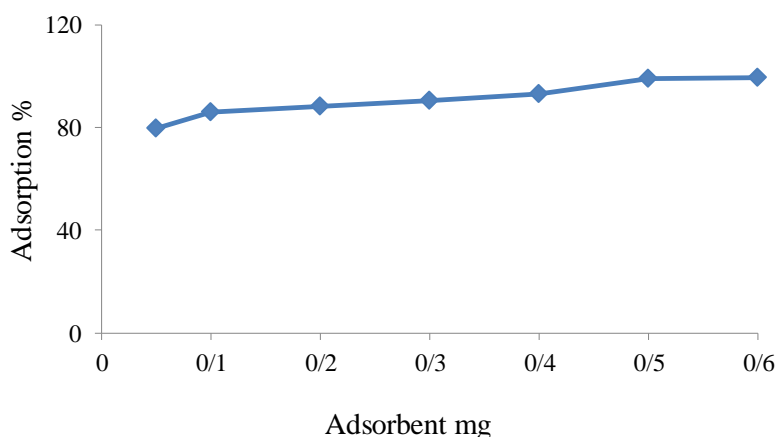


Figure 6. The Effect of Various Loading on Adsorption 30 ml Methyl Violet Solution

3.5. Adsorption Kinetic Study

The study of adsorption kinetics describes the solute uptake rate and evidently this rate controls the residence time of adsorbate uptake at the solid-solution interface. Several kinetic models are available to understand the behavior of the adsorbents and to examine the controlling mechanism of the adsorption process. In the present investigation, the adsorption data were analyzed using two different kinetic models, namely the pseudo-first-order and pseudo-second order which are shown in Figures 7 and 8.

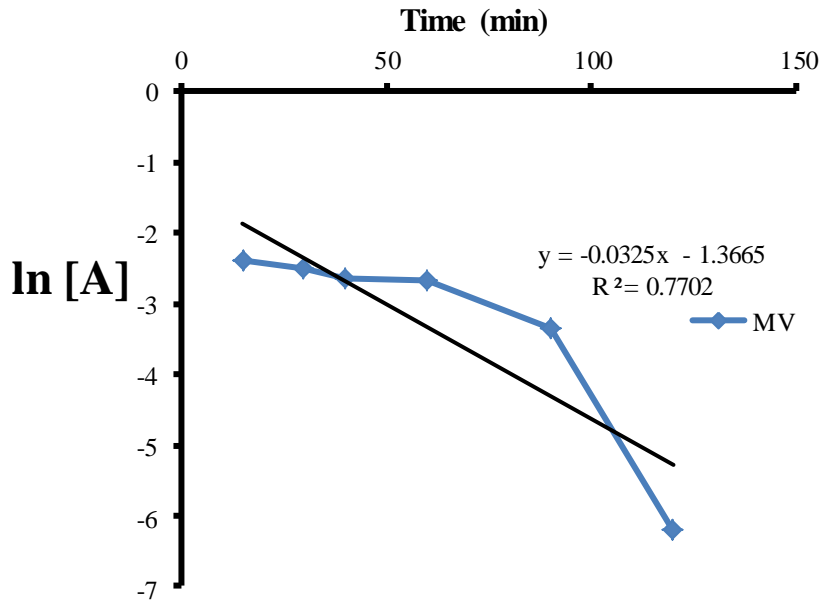


Figure 7. Kinetic Models of Pseudo-First Order for Bentonite on 30 ml Methyl Violet Solution

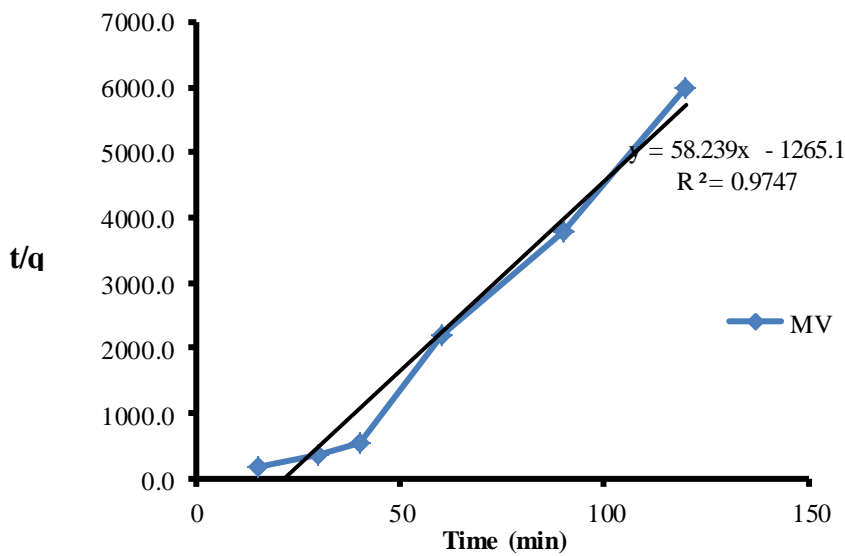


Figure 8. Kinetic Models of Pseudo-second Order for Bentonite on 30 ml Methyl Violet Solution

4. Conclusions

Batch adsorption studies were conducted to evaluate the effect of various parameters such as pH, adsorbent effect, different contact time and temperature on the removal of Methyl violet. According to results these conclusions were obtained:

- The pH of the dye solution strongly affected the chemistry of both the dye molecules and adsorbents in aqueous solutions. The optimum conditions for this study were pH 5.
- The amount of dye uptake was found to increase with increase in contact time

- The kinetic data may be useful for environmental technologists in designing treatment plants for color removal from wastewaters enriched with Methyl violet.
- The results showed that these adsorbents could potentially be used as a low-cost material for the removal of the reactive dyes in aqueous solutions.

References

- [1] M. Doğan, M. Alkan and Y. Onganer, "Water Air Soil Pollute", vol. 120, (2000).
- [2] O. Demirbas, M. Alkan and M. Dogan, "Adsorption", vol. 8, (2002).
- [3] M. Doğan and M. Alkan, Colloid Interface Sci., vol. 267, (2003).
- [4] M. Doğan and M. Alkan, Chemosphere, vol. 50, (2003).
- [5] M. Alkan and M. Doğan, Fresenius Environ. Bull, vol. 12, (2003).
- [6] M. Alkan and M. Doğan, Colloid Interface Sci., vol. 243, (2001).
- [7] P. Pendleton and S. H. Wu, Colloid Interface Sci., vol. 266, (2003).
- [8] W.T. Tsai, C.Y. Chang, M.C. Lin, S. F. Chien, H. F. Sun and M. F. Hsieh, Chemosphere, vol. 45, (2001).
- [9] G. McKay, Chem. Tech. Biotechnol., vol. 33A, (1983).
- [10] R. Leyva-Ramos, Chem. Tech. Biotechnol., vol. 33A, (1989).
- [11] K. P. Singh, D. Mohan, S. Sinha, G. S. Tondon and D. Gosh, Ind. Eng. Chem. Res., vol. 42, (2003).
- [12] G. Bereket, A. Z. Aroguz and M. Z. Ozel, Colloid Interface Sci., vol. 187, (1997).
- [13] M. M. Mohamed, Physicochem. Eng. Aspects., vol. 108, (1996).
- [14] K. K. Jain and G. Prasad, V. N. J. Chem. Tech. Biotechnol., vol. 29, (1979).
- [15] D. Mohan, K. P. Singh and G. Singh, Ind. Eng. Chem. Res., vol. 42, (2002).
- [16] V. K. Gupta, D. Mohan, S. Sharma and M. Sharma, Sep. Sci. Technol., vol. 35, (2000).
- [17] S. J. Allen, G. McKay and K. Y. H. Khader, J. Chem. Tech. Biotechnol., vol. 45, (1989).
- [18] Y. S. Ho and G. McKay, Chem. Eng., vol. 70, (1998).
- [19] G. McKay, M. S. Otterburn and A. G. Sweeney, Water Res., vol. 15, (1981).
- [20] G. S. Brady, H. R. Clauser and J. A. Vaccari, Materials handbook, (2002).
- [21] J. W. Hosterman and S. H. Patterson, U.S. Geological Survey Professional Paper, (1992).
- [22] M. Alkan, M. Doğan, Y. Turhan, O. Demirbas and P. Turan, Chemical Engineering Journal, vol. 139, (2008).

