Tea waste impregnated with iron oxide nano-particles for dye removal from aqueous solutions

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ABSTRACT – Textile dyes in wastewater can be removed by several methods including adsorption. In this study, batch experiments were conducted to determine the possibility of the removal of Basic Red 18 (BR18) textile dye from aqueous solutions using Magnetic Nanoparticles loaded Tea Waste (MNLTW). The effects of various parameters such as adsorbent dosage, solution pH, initial dye concentration and contact time were studied under room temperature and kinetic data were fitted to a pseudo second-order model. Experimental results indicated MNLTW is a potential substance that can be used for the removal of BR18 dye from wastewater.

Keywords: Magnetic Nanoparticles; Tea waste; Basic Red 18

INTRODUCTION

Wastewater containing dyes must be pre-treated by a proper method before disposing into water bodies. Treating methods such as chemical oxidation, coagulation and membrane separation have not been widely used at industrial level due to some drawbacks such as high cost and formation of toxic by-products. Adsorption is the most effective and economical method for dye removal. There are cationic (basic), anionic (acid, direct) and non-ionic dyes and BR18 is a cationic dye. In recent years, low-cost adsorbents have been used to remove different types of heavy metals and dyes (Singh, Nagpal, Agrawal, & Rachna, 2018; Amarasinghe & Williams, 2007). Adsorption of seven different organic dyes onto iron oxide nanoparticles loaded tea waste made under a vacuum have been investigated (Madrakian, Ahmadi, Madrakian, Tayyebeh, & Afkhami, 2012). This research would attempt to study the removal of BR18 dye using tea waste impregnated with iron-oxide nanoparticles under atmospheric pressure through batch experiments.

METHODOLOGY

Preparation of the calibration curve

In absorption studies, the concentration of the dye solution was determined using UV spectrophotometer at a wavelength corresponding to the maximum absorbance (λ_{max}) of the dye. To find λ_{max} for BR18 dye, 60 ppm of dye solution was prepared and UV spectrum in total range (190 - 1100 nm) was passed through the sample. Then, to draw the calibration curve, dye samples with different concentrations (10 – 70 ppm) were prepared and absorbance readings were obtained at the UV spectrum; λ_{max} (486 nm).

Preparation of Magnetic Nano-particles Loaded Tea Waste (MNLTW)

Cleaned tea waste was boiled with distilled water at 80^0C for 1h and washed with distilled water. Above step was repeated until the washing water contained no visible colour. Then it was dried in an oven at 105 ^{0}C for 10 h to remove the moisture. It was then crushed and sieved, and particles in the size range of 90-500 μm were taken.

$FeCl_3.6H_2O$ (3.1g) and $FeSO_4.7H_2O$ (2.1 g) were added to 80 ml of distilled water with vigorous stirring under atmospheric conditions. Then, 10 ml of NH_4OH solution (25 %) was added, while the solution was heated to 80^0C. Then, 10 g of pretreated tea waste was added to the solution and reaction was carried out for 45 minutes at 80^0C under constant stirring. The suspension was allowed to cool to the room temperature and filtered. Then it was washed repeatedly with distilled water to remove the unreacted chemicals.

Effect of MNLTW dosage, solution pH and initial dye concentration

Effect of adsorbent dosage was tested by varying the adsorbent dosages from 0.1 g to 1.0 g in 250 ml and 50 ppm dye samples while all the other variables such as contact time, stirrer speed, and pH of the solution were kept constant. Effect of pH was examined in the pH range 2-13. Dye concentration, dosage, sample size and contact time were 50ppm, 0.4g, 250ml and 2h. pH of the solutions were adjusted using 0.1 M HCl and 0.1 M NaOH. Effect of initial dye concentration and contact time was examined using dye solutions of three different concentrations (50,75 and 100ppm) for different contact times while pH was adjusted to its optimum value (pH=10). These data were also used for kinetic studies.

RESULTS AND DISCUSSION

Effect of change in adsorbent dosage

Surface area available for the adsorption increases with the adsorbent dosage and that results in a higher dye removal percentage at a high adsorbent dosage as shown in Figure 1. Adsorption density is the amount of dye particles that can be adsorbed by a unit amount of the adsorbent. As in Figure 2, when the contact time increases, adsorption density also increases and reaches steady-state value because adsorbents get saturated with time.

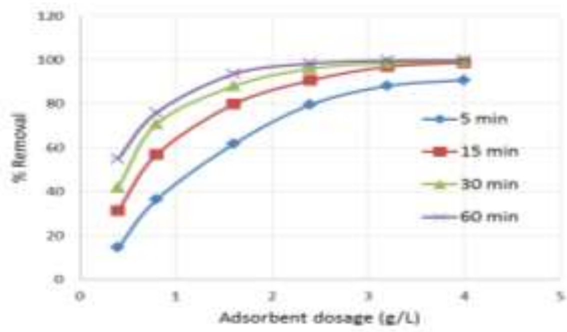

Figure 1. Percentage dye removal Vs. adsorbent dosage

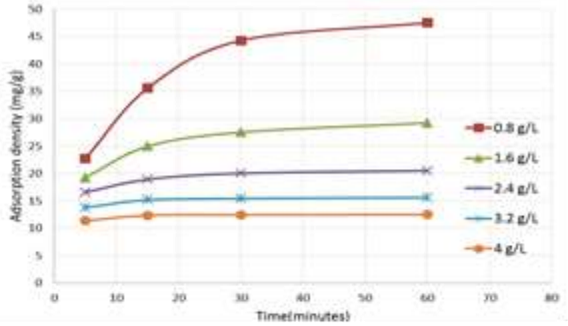

Figure 2. Adsorption density Vs. time

Effect of solution pH

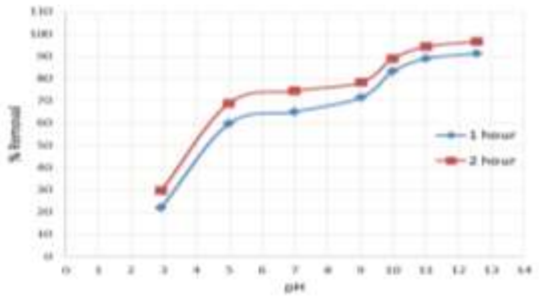

Figure 3. Percentage dye-removal Vs. solution pH

According to literature, (Baybars & Karakaş, 2013) Basic Red 18 is a cationic dye. At lower pH, MNLTW surface gets positively charged due to H^+ ions and percentage dye removal decreases due to the repulsion force between dye cations and the adsorbent surface. At higher pH, MNLTW surface gets negatively charged due to OH^- ions and adsorption increases as shown in Figure 3 due to the attraction force between dye cations and the adsorbent surface.

Effect of initial dye concentration and contact time

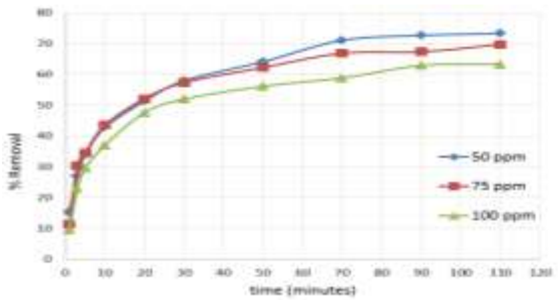

Figure 4. Percentage dye- removal Vs. contact time

As in Figure 4, with the increase of dye concentration, the interactions between dye particles and adsorbent surfaces decrease causing the dye removal to decrease. Higher interaction occurs with the increase of contact time and, it causes higher percentage removal of dye with time. Adsorbent density (q) increases with the dye concentration and contact time as shown in Figure 5.

Kinetic studies

The experimental data were fitted to pseudo-first and second-order models. The best fit model was Pseudo second order model as given in Figure 6. The equation is given by,

$$\frac{t}{q} = \frac{t}{q_e} + \frac{1}{k_2 q_e^2} \quad (1)$$

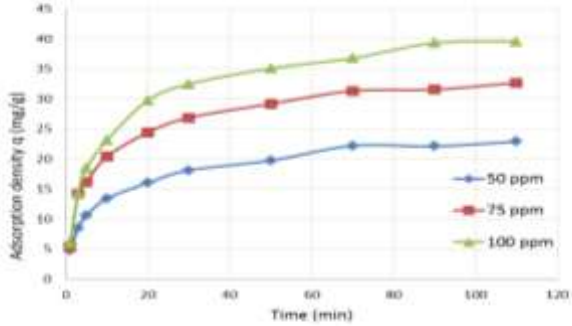

Figure 5. Adsorption density Vs. contact time

Where q, q_e and k_2 ; adsorption densities at time t, at equilibrium and adsorption rate constant respectively.

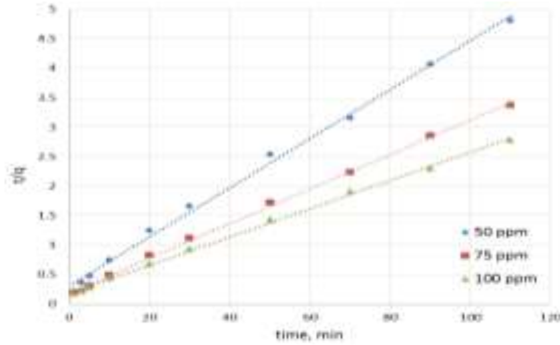

Figure 6. Pseudo-second order kinetics of BR18 onto MNLTW: 0.4g of MNLTW in 250ml dye solution, pH=10

CONCLUSION

It was found that the percentage removal decreased with the increase of initial dye concentration and increased with the adsorbent dosage. Furthermore, adsorption is dependent on pH for BR18 dye and optimum pH was 10. Highest dye uptake of 39.56 mg/g was for a concentration of 100 ppm, 250 ml solution and 0.4 g adsorbent dosage. Best fitted model for the adsorption kinetics is the pseudo- second order model with a correlation coefficient greater than 0.99. The adsorption rate constant and initial adsorption rate ($k_2 q_e^2 k_2 q_e^2$) for 100 ppm were 0.00324 g mg^{-1} min^{-1} and 5.7208 mg g^{-1} min^{-1} respectively.

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