Indian Journal of Experimental Biology
Vol. 59, August 2021, pp. 564-569

Biodecolourisation of Bismarck Brown dye using Orange peel

J John Paul, A Surendran & A Joseph Thatheyus*

PG and Research Department of Zoology, The American College, Madurai, Tamil Nadu, India

Received 03 December 2019; *revised 07 February 2021*

Dyes discharged from dyeing units and textile industries pollute the environment, particularly aquatic systems and cause considerable damage to organisms. Removal of colour is a prerequisite for discharge of treated textile effluents into the environment. Though several physical and chemical methods are available for decolourisation, biosorption is considered as cost effective and ecofriendly technique. Hence, in the present study, we explored possibilities of using orange peel for decolourisation of Bismarck brown dye, one of most common dyes used in the textile industry. Orange peel in different quantities (0.2, 0.4, 0.6 and 0.8 g/100 mL) was tested with 0, 100, 200, 300 and 400 ppm concentrations of Bismarck Brown dye for ten days. The decolourisation activity proportionally increased with the increase in the treatment period. The dye concentration of 100 ppm was tested with 0.4 g orange peel in different pH ranges of 2, 4, 6, 8 and 10 and the absorption was high in acidic pH. The increase in contact time also resulted in increased dye removal. Over all, the adsorption of dye onto orange peels was influenced by initial dye concentration, pH, amount of adsorbent and contact time. Four grams of orange peel showed highest decolourisation after 200 min, and it was proportional to the contact time. The dye removal was the maximum at pH 2. Both Langmuir (R^2 = 0.922) and Freundlich (R^2 = 0.999) adsorption isotherms were calculated.

Keywords: Biosorption, Biosorbents, Industrial effluents, Pollution, Textile industry

Disposal of waste water is one of the major problems in textile industries along with other minor problems such as solid waste and resource waste management[1]. Synthetic dyes employed in textile industries mainly affect the photosynthetic activity of plants and oxygen consumption of aquatic organisms[2]. Component metals and chlorine present in certain synthetic dyes have lethal effects on some marine organisms. Dyes are carcinogenic, mutagenic, teratogenic and toxic which produce harmful effects in all living organisms including human beings. Removal of dye is a huge task, and that the textile wastewater must be treated before discharge[3,4]. Different techniques, such as biological treatment, nanofiltration, oxidation process, ion exchange, ozonation, ultrafiltration and coagulation have been studied for the treatment of dyes from wastewater. However, these processes are expensive and ineffective to treat huge quantities of wastewater unlike adsorption which is proven to be one of the most effective techniques[5-7].

Adsorption process is effective in removing colour and soluble organic pollutants including organic dyes. The most used adsorbent in removing colours is activated carbon. However, conventional activated carbon that has been used today is expensive for a large scale of treatment[8,9]. Recently, researchers have focused on the development of low cost adsorbent for a full scale treatment[10,11]. Orange peel is a promising alternative low cost, natural adsorbent for removal of dyes. On the other hand, accumulation of orange peel waste in orange industries has been a issue as it occupies space and also causes pollution with phenolic compounds when dumped as waste. In this context, recycling of this solid waste for waste water treatment would not only be economical but also will help to solve solid waste disposal problems[12,13]. Orange peel was previously investigated to adsorb methyl orange, methylene blue, rhodamine B, congo red, methyl violet, amido black , acid violet and direct red 23 and 80[14,15]. Therefore, in the present work, we evaluated the possibility of using dried orange peel to develop a new low cost activated carbon and study its application to remove Bismarck brown which is currently among the widely used commercial dyes in the printing of cotton and mucilage glue fabrics as well as dyeing of silk and wool.

Materials and Methods

Characterization of orange peel

Orange peel was collected from local fruit juice shops and washed with tap water followed by

*Correspondence:
E-Mail: jthatheyus@yahoo.co.in

washing with distilled water. After this, the clean orange peel biomass was oven dried at 105°C for 96 h. Characterization of orange peel was done using FTIR analysis (FTIR-4600, JASCO International Co., Ltd).

Preparation of activated carbon from orange peel biomass

The dried orange peel biomass was added in small portion to 98% of nitric acid and kept for 2 h and the resulting reaction mixture was cooled by adding cold water and filtered. The resulting material was heated in an oven at 150°C for 24 h.

Preparation of test solution and Determination of absorption maxima

Bismarck brown dye concentrations @100, 200, 300 and 400 ppm were prepared for 100 mL volume with distilled water. The dye solution was taken in a cuvette and placed in a colorimeter and absorbance value at each wavelength was observed using distilled water as blank. The wavelength which showed the maximum absorbance was chosen as the absorption maxima[12,13].

The carbon activated dried orange peel of about 0.2, 0.4, 0.6 and 0.8 g was introduced into the dye solutions. Initial absorbance was measured and the solutions were observed periodically for the absorbance values. The test samples were taken in a cuvette and placed in the colorimeter. The absorbance was noted periodically at an interval of 48 h at the wavelength of 450 nm which is the absorption maxima. The decolourisation activity was expressed in terms of percentage decolourisation as determined by monitoring the decrease in the absorbance at the absorption maxima of the dye[12,13]. Decolourisation activity was calculated according to the following formula:

$$\text{Decoloursiontion activity (\%)} = \frac{\text{(Initial absorbance)} - \text{(Observed absorbance)}}{\text{Initial absorbance}} \times 100$$

Isotherm and data analysis

Isotherm and data analysis

The relationship between the amount of a substance adsorbed at constant temperature and its concentration in the equilibrium solution is called the "adsorption isotherm”. Equilibrium isotherm equations are used to describe the experimental adsorption data. The most widely accepted surface adsorption models for single-solute systems are the Langmuir and Freundlich models. The correlation with the amount of adsorption and the liquid phase concentration was tested with the Langmuir[16] and Freundlich[17] isotherm equations. Linear regression was frequently used to determine the best fitting isotherm.

Langmuir isotherm

Langmuir isotherm model assumes uniform energies of adsorption on to the surface without transmigration of adsorbance in the plane of the surface. Therefore, the Langmuir isotherm model was chosen for the estimation of the maximum adsorption capacity corresponding to complete monolayer coverage on the adsorbent surface. The Langmuir non-linear equation is commonly expressed as follows:

$$q_e = Q_0\, b\, C_e / (l + b\, C_e)$$

where qe, equilibrium adsorption capacity (mg/g); C_e, equilibrium concentration of adsorbate (mg/L); Q_0, Monolayer surface coverage (mg/g); b, the equilibrium adsorption constant (L/mg); Q_0 and b are the Langmuir constants related to capacity and energy of adsorption, respectively. The linear form of the Langmuir isotherm can be expressed as follows:

$$1/q_e = (1/Q_0) + (1/b\, Q_0 C_e)$$

Freundlich isotherm

The Freundlich isotherm model is the earliest known equation describing the adsorption process. The Freundlich non linear equation is expressed as follows:

$$q_e = K_f C_e^{1/n}$$

where, q_e, the amount of metal ions adsorbed per unit weight of adsorbents (mg/g); C_e, equilibrium concentration of adsorbate (mg/L); K_f and 1/n are the Freundlich constants that are dependent on several environmental factors.

The linear form of the Freundlich equation which is commonly used to describe the adsorption isotherm data is

$$\text{Log } (q_e) = \log K_f) + 1/n \log C_e$$

Results and Discussion

FTIR analysis of orange peel

The presence of characteristic peaks such as 3423.99 cm^{-1}, 1626.63 cm^{-1}, 916.986 cm^{-1}, 760.065 cm^{-1}, 723.17 cm^{-1} and 666.285 cm^{-1}, at three different ranges 3500-3300 cm^{-1}, 1650-1590 cm^{-1}, 900-650 cm^{-1} can be observed in FTIR analysis of orange peel (Fig. 1). They are a strong indication for the presence of N-H (amine group) in the sample. Broad weak peaks at 2396.12 cm^{-1} could indicate the presence of alkyne (C≡C) stretching in the sample. Broad medium multiple peaks around 1760 cm^{-1} and 1740 – 1715 cm^{-1} (1762.62 cm^{-1} and 1730.8 cm^{-1}) might reveal the C=O stretching due to carboxylic acid in monomer form,

Fig. 4 — (A) Langmuir isotherm and (B) Freundlich isotherm for Bismarck brown treatment using orange peel

isotherm is characterized by some particular constant values that exhibit the properties of the surface and affinity of the adsorbent and can even be used to compare the adsorptive capacities of that particular adsorbent for various adsorbates[22]. The most common models at constant temperature for this sort of adsorption are Langmuir isotherm and Freundlich isotherm[19,20]. In the present work, the isotherm studies were carried out for optimum condition, which was obtained (Fig. 4). The R^2 values suggest that the Langmuir isotherm (0.922) and Freundlich isotherm (0.999) provide good models for sorption.

Conclusion

From this study, it may be concluded that the removal of Bismarck brown dye from textile wastewater by adsorption on orange peels has been found to be useful for controlling water pollution due to dyes. From this experiment it is clear that the adsorption of dye onto orange peels is influenced by pH, amount of adsorbent and contact time. Orange peel (0.4 g) exhibited the highest activity of decolourisation after 200 min, and the activity increased with the increase in contact time. The activity decreased with the increase in initial dye concentration. The dye removal was highest at pH 2. Also, the adsorption of dye onto orange peels followed the Langmuir and Freundlich isotherm models.

Conflict of interest

Authors declare no competing interests

References

1 Ghaedi M, Tavallali H, Sharifi M, Kokhdan SN & Asghari A, Preparation of low cost activated carbon from *Myrtus Communis* and pomegranate and their efficient application for removal of congo red from aqueous solution. *Spectrochim Acta A Mol Biomol Spectrosc*, 86 (2012) 107.

2 Gupta VK & Suhas A, Application of low-cost adsorbents for dye removal – A review. *J Environ Manag*, 90 (2009) 2313.

3 Siddiqui SI, Fathima B, Tara N, Rathi G & Chaudhry SA, Recent advances in remediation of synthetic dyes from waste waters using sustainable and low-cost adsorbents. In: *The Impact and Prospects of Green Chemistry for Textile Technology*, under The Textile Institute Book Series. (Eds. Shahid-ul-Islam & Butola BS; Woodhead Publishing, Elsevier, New Delhi), 2019, 471-507.

4 Allen SJ & Koumanova B, Decolourisation of water/ wastewater using adsorption (review). *J Univ Chem Technol Metall*, 40 (2005) 175.

5 Bharathi KS & Ramesh ST, Removal of dyes using agricultural waste as low-cost adsorbents: a review. *Appl Water Sci*, 3 (2013) 773.

6 Maraj EN, Shaiq S & Iqbal Z, Assessment of hexahedron and lamina shaped graphene oxide nanoparticles suspended in ethylene and propylene glycol influenced by internal heat generation and thermal deposition. *J Mol Liq*, 262 (2018) 275.

7 Siddiqui SI & Chaudhry SA, Nanohybrid composite Fe2O3-ZrO2/BC for inhibiting the growth of bacteria and adsorptive removal of arsenic and dyes from water. *J Cleaner Prod*, 223 (2019) 849.

8 Rehorek A & Plum A, Characterization of sulfonated azo dyes and aromatic amines by pyrolysis gas chromatography/ mass spectrometry. *Anal Bioanal Chem*, 388 (2007)1653.

9 Aljeboree AM, Alshirifi AN & Alkaim AF, Kinetics and equilibrium study for the adsorption of textile dyes on coconut shell activated carbon. *Arabian J Chem*, 10 (2017) S3381.

10 Tara N, Siddiqui SI, Rathi G, Chaudhry SA & Asiri AM, Nano-engineered Adsorbent for the removal of dyes from water: A review. *Curr Anal Chem*, 16 (2020) 14.

11 Siddiqui SI, Zohra F & Chaudhry SA, *Nigella sativa* seed based nanohybrid composite-Fe_2O_3–SnO_2/BC: A novel material for enhanced adsorptive removal of methylene blue from water. *Envt Res*, 178 (2019) 108667.

12 Pathania D, Sharma A & Siddiqi Z, Removal of congo red dye from aqueous system using Pheonix dactylifera seeds. *J Molecular Liquids*, 219 (2016) 359.

13 Pelaez-cid AA, Herrera-Gonzalez AM, Salazar-Villanueva M & Hernandez BA, Elimination of textile dyes using activated carbons prepared from vegetable residues and their characterization. *J Environ Manag*, 181(2016) 269.

14 Mozumder MSI & Islam MA, Development of treatment technology for dye containing industrial wastewater. *J Sci Res*, 2 (2010) 567.

15 Amin NK, Removal of reactive dye from aqueous solutions by adsorption onto activated carbons prepared from sugarcane bagasse pith. *Desalination*, 223 (2008) 152.

16 Langmuir I, The adsorption of gases on plane surface of glass, mica and platinum. *J Am Chem Soc*, 40 (1916) 1361.

17 Freundlich HMF, Over the adsorption in solution. *J Phys Chem*, 57 (1906) 385.

18 Adeyemo AA, Adeoye IO & Bello OS, Adsorption of dyes using different types of clay: a review. *Appl Water Sci*, 5 (2015) 407.

19 Mohd Salleh MA, Mahmoud DK, Wan Abdul Karim WA & Idris A, Cationic and anionic dye adsorption by agricultural solid wastes: A comprehensive review. *Desalination*, 280 (2011) 1.

20 Heibati B, Rodriguez-Couto S, Al-Ghouti MA, Asif M, Tyagi I, Agarwal S & Gupta, Kinetics and thermodynamics of enhanced adsorption of the dye AR 18 using activated carbons prepared from walnut and poplar woods. *J Molecular Liquid*, 208 (2015) 99.

21 Yeddou N & Bensmaili A. Kinetic models for the sorption of dye from aqueous solution by clay-wood saw dust mixture. *Desalination*, 185 (2005) 499.

22 Babel A & Kurniawan TA, Low-cost adsorbents for heavy metals uptake from contaminated water: A review. *J Hazard Mater*, 97(2003) 219.

23 El-Sayed GO, Yehia MM & Asaad AA, Assessment of activated carbon prepared from corncob by chemical activation with phosphoric acid. *Water Resour Ind*, 7 (2014) 66.

24 Khaled A, El-Nemr A, El-Sikaily A and Abdelwahab, Removal of direct N blue 106 from artificial textile dye effluent using activated carbon from orange peel: adsorption isotherm and kinetic studies. *J Hazard Mater*, 165 (2009) 100.