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# Asparagine functionalized MWCNTs for adsorptive removal of hazardous cationic dyes: Exploring kinetics, isotherm and mechanism

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A B S T R A C T

In present work, a novel asparagine functionalized multiwalled carbon nanotube (Asp-CNT) was synthesized and characterized by SEM-EDX, and FTIR spectroscopy. Synthesized nanomaterial was used as an effective adsorbent for removal of hazardous cationic dyes like Malachite green (MG) and Methylene blue (MB) from water in single and binary system. The adsorption parameters like contact time (0-90 min), stirring speed (200-800 rpm), pH (2-9), adsorbent dosage (5-25 mg), initial dye concentration (10-350 mg $L^{-1}$) and the temperature (25-55°C) were optimized. The adsorption capacities obtained under optimum conditions were 637 mg $g^{-1}$ and 500 mg $g^{-1}$ for MG & MB respectively. The kinetic and equilibrium studies were performed using different models. The active investigation of kinetic and equilibrium studies demonstrated that the adsorption process followed pseudo second order and Langmuir model ($R^2 > 0.99$) for both dyes, which infers monolayer adsorption occurred via chemisorption. The simultaneous adsorption study of MG and MB in a binary system showed that MB has faster adsorption rate than MG which can be explained on the basis of structure of dyes. The high adsorption capacity of Asp-CNT for both dyes was explained with the help of adsorption mechanism and further confirmed by FTIR spectra of dyes saturated Asp-CNT. Desorption study of both dyes was conducted using various eluents. It was observed that the adsorbent could be easily regenerated by mixture of acid and ethanol and reused for 3 cycles without altering the adsorption efficiency. Hence, it is concluded from adsorption studies that the synthesized nanomaterial has a great potential to be used for large scale wastewater treatment.

## 1. Introduction

Dyes are extensively used in leather, textile, cosmetics, paper, and pharmaceutical industries where they make goods attractive by imparting beautiful colours. The production of dyes in various industries is increasing drastically as to cover the demand of such a large population. It is estimated that the annual production of commercial dyes is more than 0.7 million ton per year and such extensive production and dumping the effluents of dyes became the major cause of water contamination. The toxic dyes and their degradation products in wastewater have non-biodegradable aromatic amines as a main constituent, which is well-known carcinogen. Water being versatile solvent is easy carrier for such hazardous dyes to enter food chain and once entered, have considerable deleterious effects on all living beings. The prolonged exposure of such toxic dyes has severe detrimental effect on human body which includes respiratory disorders, skin irritation, allergic reaction etc. [1]. Therefore, the treatment of wastewater containing the effluents of harmful dyes is highly essential for sustainable development. There are various methods such as membrane filtration, coagulation-flocculation, oxidation, photo-degradation [2], biological and adsorption [3] have been applied so far for the treatment of dye contaminated wastewater. Most of these techniques have complex treatment process and consumes more time and energy. They are also not economic due to high cost of reagents. Among all, adsorption is one of the most convenient and widely used techniques due to its simple treatment process, use of variety of adsorbents and no production of harmful secondary by-products. This makes it highly efficient technique for removal of dyes from wastewater [4]. The various adsorbents like activated carbon [5], zeolites [6], silica [7], metal oxides [8], clays [9], hydrogels [10] and cellulose [11] have been extensively used for this purpose. The detection of dyes is generally done by UV-visible spectrophotometer but other hyphenated techniques like GC-MS (Gas Chromatography – Mass Spectrometry), LC-MS (Liquid Chromatography – Mass Spectrometry), and HPLC (High-Performance Liquid Chromatography) [12–14] are also used. All these hyphenated techniques are capable of removing dyes and other pollutants like toxic metal ions from

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