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# Adsorption studies on treatment of textile dyeing industrial effluent by flyash

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**Abstract**

Textile effluents are highly toxic as they contain a large number of metal complex dyes. The high concentration of such dyes causes many water borne diseases and increases the BOD of the receiving waters. On the other hand, flyash is a major pollutant generated in coal-based thermal power plants and has potentiality for use as an adsorbent. In the present work, adsorption studies were made in treating the dye solutions of methylene blue (M-B) and Congo red (CR) textile dyes by using flyash. Effects of quantity of adsorbent, time of contact, initial effluent concentration, pH and temperature have been investigated experimentally and the results were compared with those obtained by using activated carbon. The first-order adsorption rate constants were determined and found decreasing with temperature. The results obtained were fitted by Langmuir model since monolayer formation observed. Also, Langmuir adsorption isotherm parameters were estimated from the experimental data obtained for both methylene blue and Congo red dyes using both the adsorbents.



*Keywords:* Dyeing industrial effluent; Methylene blue dye; Cong red dye; Flyash; Activated carbon; Adsorption; Percentage of colour removal; Equilibrium concentration; First-order rate constants; Langmuir isotherm parameters

## 1. Introduction

Industrial development is directly related to quantity of power generation and utilization in any country. Therefore, industrial development and environmental pollution go hand in hand. In India, where a projected quantity of about 250 million tonnes of coal and lignite are to be used in power generation by the year 2010, an estimated 80–100 million tonnes of flyash will be generated. The concentration and effective utilization of flyash generated from burning fuels in thermal power plants have attracted worldwide attention in view of the large disposal problems without detriment to environment. The potentiality of flyash as catalyst in destructive decolourization of various aqueous dye solutions using hydrogen peroxide was reported [1,2]. Also, it is widely reported that flyash generated from coal/lignite fired thermal power stations is a very good adsorbent for colour removal [3].

On the other hand, India is facing another type of environmental problem. Thousands of small-scale dyeing units, employing millions of people, generate enormous amount of polluted water. Mostly, the areas situated around industrial belts are under stress due to the continuous disposal of the untreated water. The quality of water is continuously deteriorating due to addition of toxic dyeing effluents. Dyeing effluents from textile industries are highly toxic as they contain a large number of metal complex dyes [4,5] (e.g. Cr and Co complexes). The high concentration of such dyes causes many water borne diseases and increases the BOD of receiving waters [6]. Hundreds of small-scale dyeing industries are facing closure since they are not treating their effluents. It is not economical for them to treat the effluent. Hence, it is imperative that a suitable treatment method should be devised.

Also, though activated carbon is an ideal adsorbent for organic matter due to its organophilic character, it is not economical for wastewater treatment owing to its high production and regeneration costs, and about 10–25% loss during regeneration by chemical or thermal treatment. High cost of activated carbon and synthetic resins in India has promoted seconds for cheaper substitutes such as flyash [1]. The equilibrium adsorption of dyes onto several low-cost adsorbents such as peat, wood, chitin, chitosan, palm-fruit bunch, biogas residual slurry etc., was studied previously [9–13]. The suitability of flyash to remove dye colours and factors governing the adsorption phenomena is to be

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**Nomenclature**

| | |
|---|---|
| $b$ | Langmuir constant related to energy of adsorption (l/mg) |
| $C_{Ae}$ | equilibrium concentration of dye on adsorbent (mg/l) |
| $C_{Be}$ | equilibrium concentration of dye in solution (mg/l) |
| $C_e$ | equilibrium concentration of dye (mg/l) |
| $K_C$ | equilibrium constant |
| $K_T$ | overall rate constant (min$^{-1}$) |
| $k_1$ | rate constant of adsorption (min$^{-1}$) |
| $k_2$ | rate constant of desorption (min$^{-1}$) |
| $q_e$ | amount of dye adsorbed at equilibrium (mg/g) |
| $Q^0$ | Langmuir constant related to capacity of adsorption (mg/g) |
| $t$ | time (min) |
| $u(t)$ | fractional attainment of equilibrium |

fully understood. In the present work, adsorption studies are carried out for treatment of dyeing effluents by using flyash and activated carbon as adsorbents. Flyash obtained from Vijayawada Thermal Power Plant (VTPS), Vijayawada & National Thermal Power Corporation (NTPC), Ramagundam and activated carbon from M/S R.K. Carbons, Hyderabad in Andhra Pradesh, India were used for studies.

## 2. Materials and methods

### 2.1. Characteristics of flyash

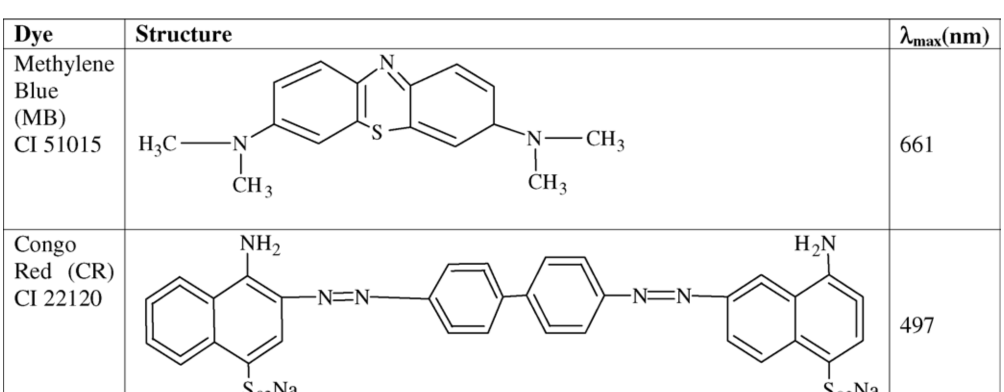
Flyash is a finely divided residue resulting in from the combustion of powdered coal or lignite and collected from flue gas of pulverized fuel fired boilers with the help of electrostatic precipitators. It is generally gray in colour, abrasive, refractory, acidic in nature. It has a specific surface area, which varies between 2500 and 7000 cm$^2$/g. Particle size of flyash ranges from as high as 120–960 μm to less than 5 μm. The specific gravity is found to vary between 2.3 and 2.5 and bulk density is in the range of 600–900 kg/m$^3$. Flyash possesses an adsorbent capacity, which depends mainly on the amount of unburnt substances within its surface, usually ranging from 12 to 30% by weight [7]. Chemical composition of flyash is given in Table 1. This adsorbent capacity allows the removal from wastewaters of either the colour or the soluble and suspended organic pollutants. Flyash is found to have also good settling capacity, which enables it to remove suspended solids by behaving as a “settling aid”. The quick flyash settling also provokes the formation of an impermeable layer on the bed of the receiving body which prevents the pollutants from going up to the surface water. It has been noticed that the increase of water hardness induced by flyash addition is not remarkable [7]. Further more, calcium salts contained in flyash (mainly $CaSO_4$ and CaO) lead to the neutralization of acid waters and alkaline dephosphorisation up to such low concentrations as to permit the reduction of the eutrophications phenomena [8]. By such adsorptive treatment of effluents from chemical industries and textile dying industries with different amounts of flyash, significant reductions induced in COD and adsorbance was clearly observed.

Table 1
Chemical composition of flyash

| Content | Flyash from VTPS (%) | Flyash from NTPC (%) |
|---|---|---|
| $SiO_2$ | 63.14 | 54.02 |
| $Al_2O_3$ | 24.63 | 28.10 |
| $Fe_2O_3$ | 3.00 | 5.15 |
| CaO | 2.15 | 3.85 |
| MgO | 1.65 | 2.25 |
| $SO_3$ | 2.25 | 3.75 |
| Alkalies | 2.11 | 1.16 |
| Combustibles | 1.07 | 1.72 |

### 2.2. Experimental aspects

Flyash and activated carbon are used for experimental purpose as adsorbents and methylene blue (MB) liquor dye and Congo red (CR) basic dye as synthetic effluents. Chemical structures of dyes used for experiments are shown in Scheme 1. Initially, the flyash has been washed several times with hot (60 °C) distilled water, filtered and dried. The sample has been then treated with dilute sulfuric acid and washed with distilled water to remove the excess sulfuric acid. Then it is heated at




Scheme 1. Chemical structure of dyes used for experiment.