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Coal-based fly-ash waste material as adsorbent for removal of textile colorants from aqueous solution

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ABSTRACT

Adsorption of some common textile dyes viz. Congo red, T-Blue, Blue 2B and Sky blue on the surface of the flyash has been investigated spectrophotometrically as a function of flyash, dye concentrations, contact time and pH (4.0 – 9.0). At a constant temperature, increase in flyash dose (1-5gm) increased the amount of adsorption (20-90%) of dye species. Adsorption data fitted to Freundtich isotherm were found to be linear for all the dyes under investigation. Extent of adsorption of above dyes was found to be almost unchanged over the studied pH range 4.0 to 9.0.

KEYWORDS

Adsorption;
Textile dyes;
Flyash;
Water pollution.

INTRODUCTION

Dyes and pigments represent one of the problematic groups; they are emitted into wastewaters from various industrial branches, mainly from the dye manufacturing and textile finishing. Dyes can cause allergic dermatitis, skin irritation, cancer, and mutations. Currently, many methods, such as activated carbon adsorption, chemical oxidation, reverse osmosis, coagulation and flocculation, and biological treatments, have been developed for treating dye-containing wastewater[1]. The adsorption process provides an attractive alternative for the treatment of contaminated waters, especially if the sorbent is inexpensive and does not require an additional pre-treatment step before its application. The use of fly ash for the removal of dye from aqueous solution was first reported by Khare et al[2].

The chemical coagulation process effectively decolorizes insoluble dyes, but it fails to work well with soluble dyes. Chemical oxidation is effective, but the oxidant requirements are very high and thus expensive. Photochemical degradation in aqueous solution is likely to progress slowly, as synthetic dyes are, in principle designed to exhibit high stability to light. Although biological treatment processes remove BOD, COD, and suspended solids to some extent, they are largely ineffective in removing color from wastewater, as most dyes are toxic to the organisms used in such processes. However, all of these methods suffer from one or other limitations, and none of them were successful in completely removing the color from wastewater. These technologies do not also show significant effectiveness or economic advantage. Low-cost treatment methods have, therefore, been investigated for a long time. Adsorption has been used extensively in industrial processes for separation and purification. In wastewater treatment, commercially activated carbon has long been used as a standard adsorbent for color removal. In spite of its widespread use in various cleaning procedures, activated carbon remains expensive; therefore, the development of low-cost alternative adsorbents has been the focus of recent research[3,4]. Contributions in this regard have been made by many researchers who have utilized a number of substances such as agricultural wastes: coir pith, banana pith, sugar cane dust, sawdust, activated carbon fibers and rice hulls[5-9], industrial solid wastes: fly ash, red mud and shale oil ash[2,10-16], and so forth.

Dye removal through conventional methods involving physicochemical as well as biological treatments seems to be inadequate as today's acceptable and recommended for discharge of effluent due to persistence of color. The production of dyes in India has been increasing with years as a result of growing textile and handloom industries. A number of synthetic dyes that are emitted (an average of 180L of wastewater is released per kg of cloth prepared) from various textile zones cause formidable contamination of water as the color tends to persists even after the conventional treatment given to the waste water.

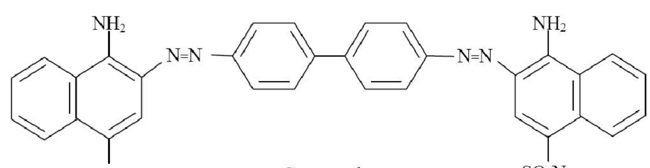
In view of the acute need of for exploring a cheap and potentially viable system and our present research interest in pollution abatement program the present work is conceived based on the capability of fly ash towards adsorbing organic molecules reported recently[17] and vulnerability of surface adsorbed organic dyes towards aerial oxidation in presence of light[18]. Author wish to report herein the results of his studies on adsorption of some common textile dyes viz. Congo red, Green B, T-Blue, Rosaniline on the surface of the flyash. The results of the present studies imply rational viability of using flyash for eco-friendly removal of dyes in textile waste-water.

EXPERIMENTAL

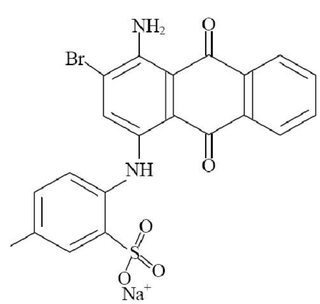
Flyash was obtained form Durgapur Project Limited, Durgapur, West Bengal. The coarser impurities in flyash were separated from by vigorous stirring of flyash suspension and allowing the coarser particles to settle. The flyash material was then dried at room temperature and used throughout the experiments. Chemical analysis of flyash was carried out for its main constituents like silica, alumina and iron oxides by using a Perkin Elmer Atomic Absorption Spectrometer (AAnalyst 300). Percentage (%w/w) of silica, alumina and iron oxides were found to 58.5, 22.7 and 5.8, respectively.

An empirical formula for fly ash based on the dominance of certain key elements has been proposed as[19]: Si1.0Al0.45Ca0.51Na0.047Fe0.039Mg0.020 K0.013Ti0.011.

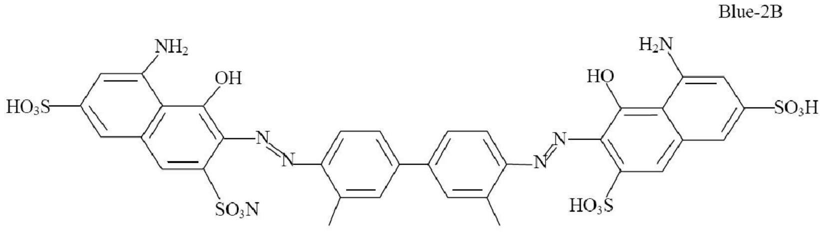
Adsorption of textile dyes viz. Congo red, Blue 2B, T-Blue and Sky Blue on flyash was estimated spectrophotometrically by using a Cintra 10 GBC UV-visible spectrophotometer. Dye samples purchased locally were used as received. And their structures are given below:



Congo red



Blue-2B



T-Blue

Doubly-distilled water was used throughout the experiments. Adsorption studies was carried out through batch experiments by shaking aqueous solution (50ml) of dyes of various concentrations containing required amount of flyash in a series of BOD bottles. The extent of adsorption was estimated by measuring the difference in absorbance of free dye and the supernatant liquid obtained after centrifugation of the reacting mixture containing flyash and dyes.

The percentage removal of dye, p, was calculated using the following equation:

$$p = \frac{(Co - Ce)}{Co} \times 100$$

where *Co* and *Ce* are the initial and equilibrium dye concentration (mg/L), respectively. All experiments were replicated and the average results were used in data analysis.

The pH of the system was adjusted by using HCl and NaOH.

RESULTS AND DISCUSSION

The composition of the flyash (see experimental) with regards to its major constituents reveals that the percentage (%w/w) of silica, alumina and oxides of iron fall in the range that expected for flyash generated in the Thermal Power Stations[20]. Results of the adsorption of dyes studied by estimating percentage deletion of dyes as a function of flyash dosage are summarized in Figure 1, whereas effect of dye concentrations on the adsorption of dye staff is shown in TABLE 1. TABLE 2 demonstrates the degree of adsorption with contact time. The dye uptake by flyash enhances with increase in amount of flyash (Figure 1), while, for a given amount of flyash percentage of unadsorbed dyes increases with the increase in initial concentration of dyes (TABLE 1).

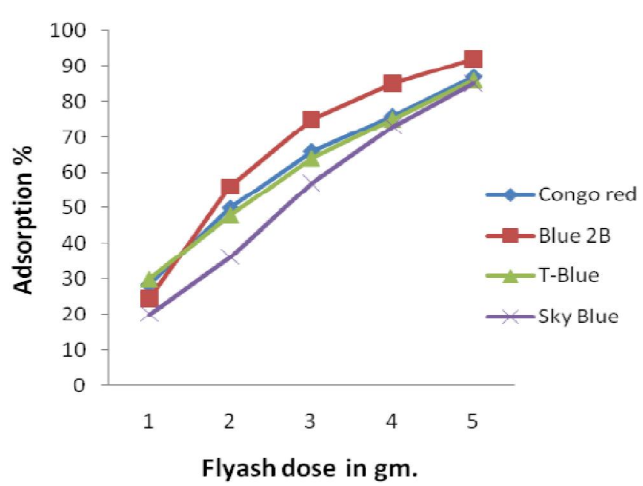


Figure 1 : Effect of flyash dose on adsorption

The percentage removal of dyes increases sharply with time initially, however, attained a limiting value after a certain period of time (TABLE 2). Results of adsorption studies reveal that the capacity of flyash towards adsorption of dyes under investigations is appreciably. No appreciable change in adsorption for the dyes undertaken in this study was noticed in the pH range 4.0 to 9.0.

TABLE 1 : Effect of dye concentration on adsorption

Concentration (ppm)	Adsorption (%)			
	Congo red	Sky blue	Blue 2B	T-blue
10	28.4	20	24.5	30
20	20.6	14.1	16.1	22.7
30	16	10.7	12.6	20.8
40	12.6	9.5	9.7	19
50	13.5	9.5	8.5	17.2

Flyash taken 1 gm, Contact time = 1 hr, temp. = 30^{0}C

TABLE 2 : Effect of time on dye adsorption

Time (mins.)	Adsorption (%)			
	Congo red	Blue 2B	T-Blue	Sky blue
10	25.1	10	16	13.6
20	27.8	15	22	17.7
30	28.4	18	26	18.2
40	28.4	20	28.2	18.6
60	28.4	24.5	30	20

[Dye] =10ppm, Flyash= 1 gm., temp. = 30^{0}C

The adsorption data of all the dyes at various concentrations have been fitted to Freunditch isotherm as expressed by the following equation:

$$x/m = 1/n \log C_e + \log K \quad (1)$$

where x/m is the amount of adsorbed dye per unit weight of adsorbent i.e. flyash, C_e is equilibrium concentration n & K are constants representing intensity of adsorption and adsorption capacity respectively. A good linearity was observed in the plot of logx/m vs logC_e (Figure 2) in each case, substantiates the applicability of Freunditch isotherm in the present case. The values of K and n determined from the corresponding plots of logx/m vs logC_e for the dyes under investigation are summarized in TABLE 3. The adsorption parameters (TABLE 3) are suggestive of the fact that the flyash obtained from Durgapur Project Limited, Durgapur, West Bengal possess reasonably good dye adsorbing capacity. Scanning Electron Microscopic (SEM) picture (Figure 3b) shows the agglomeration of the dye on the surface of the flyash.

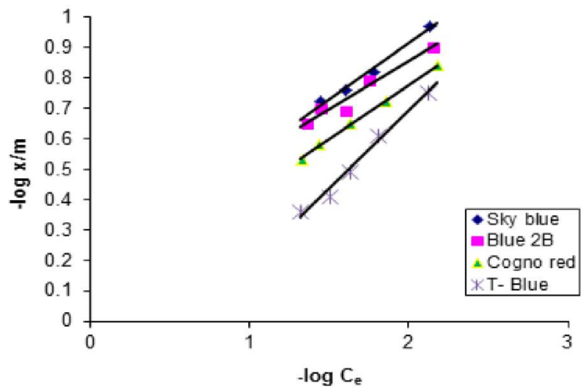


Figure 2 : Freundlich isotherm at 30°C

TABLE 3 : Adsorption parameters derived from Freundlich isotherm

Dyes	K	n
Congo red	0.79	2.92
Blue 2B	0.71	2.92
T- blue	1.58	2.25
Sky blue	0.66	2.43

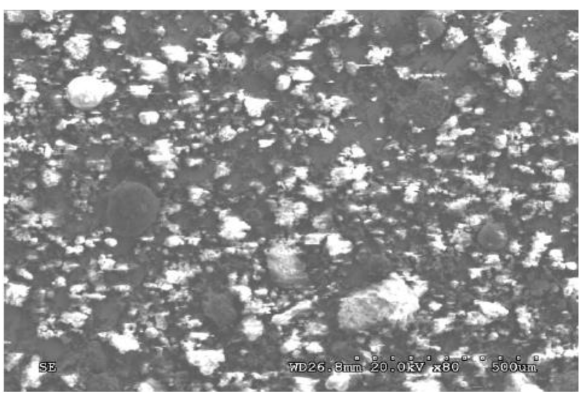


Figure 3a : SEM picture of flyash

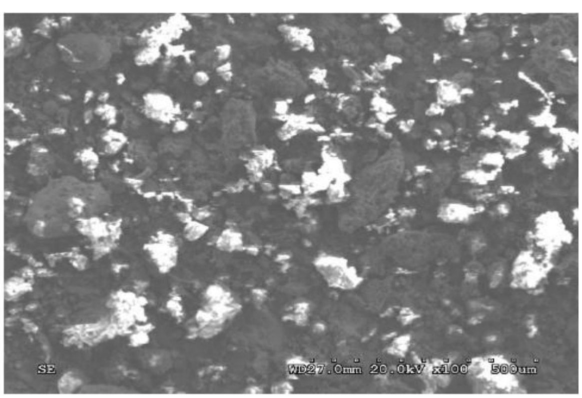


Figure 3b : SEM picture showing the agglomeration of the dye on the surface of the flyash.

CONCLUSION

In conclusion, the results of the present work evidently display the dye adsorbing capacity of flyash obtained from Durgapur Project Limited, Durgapur, West Bengal. The results of the present studies imply rational viability of using flyash for color removal form waste water. However, the vital intricacy in the present system is associated with regard to its repeatability as the adsorption sites are blocked at the higher concentration of the colorants. Conceptually photo degraation of the adsorbed dye molecules in presence of visible light would offer an eco-friendly dye removal technique in textile waste-water treatment. Fly ash can be regarded as a low-cost resource or industrial minerals. It is mainly composed of aluminosilicate and unburned carbon. Investigations have demonstrated that fly ash possesses adsorption capacity for removal of gaseous pollutants in air, inorganic ions and organic compounds in water.

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