

# Bottom Ash as A Potential Waste Material For The Removal of Toxic Fast Green Fcf and Phenol Red From Waste Water: A Comparative Account

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**Abstract.** Elimination of toxic dyes from waste water is a subject of prime concern. In the present research Bottom Ash (BA), a waste of the thermal power plants has been utilized for the elimination of toxic Fast Green FCF (FCF) and Phenol Red (PR) dyes from waste water by adsorption process. The research deals with the study of various factors including the effect of pH, mesh size, adsorbent dose, concentration of the dye solutions. The collected data was then used to design Langmuir isotherm. Maximum adsorption was observed at 50 °C indicating the endothermic nature of the adsorption process. The adsorption was found to be spontaneous as indicated by the values free energy. The order of entropy was PR < FCF, with the values 88.6 and 312.35 JK<sup>-1</sup>. mol<sup>-1</sup> for PR and FCF dyes respectively.

**Key words:** Fast Green FCF; Phenol Red; Bottom Ash; Langmuir; Adsorption

## 1. Introduction

Dyes are the most visible water pollutants. These dyes are let into the water bodies by effluents from textile industries and several laboratories. Dyes in water bodies reduce light penetration and most of the dye stuff used in these industries and labs is toxic and non biodegradable [1]. Triarylmethane class of dyes like Fast Green FCF (FCF) C<sub>37</sub>H<sub>34</sub>N<sub>2</sub>O<sub>10</sub>S<sub>3</sub>Na<sub>2</sub> and Phenol Red (PR) C<sub>19</sub>H<sub>14</sub>O<sub>5</sub>S used as colorants in textile industries and in several laboratory applications are toxic, mutagenic and carcinogenic which makes their removal a matter of prime concern. Several substances have been employed for the elimination of the toxic dyestuffs including activated carbon [2-4]. The present research is an attempt to employ Bottom Ash (BA) a waste of thermal power plants as an adsorbent for the elimination of FCF and PR from waste water.

## 2. Experimental

Dye solutions FCF and PR (M/s Merck) of particular concentrations were brought into contact with weighed amount of the adsorbent (BA) (procured from thermal power station (TPS) of M/s Bharat Heavy Electrical Limited (B.H.E.L.), Bhopal (India)), for about 24hrs after which the amount of the dye adsorbed was determined spectrophotometrically by UV-Vis spectrophotometer Model Number 117 (M/s Systronics, Ahmedabad, India) at  $\lambda_{\max}$  622nm for FCF and 435nm for PR.

## 3. Effect of pH:

The adsorption of the dyes was studied in a wide range of pH ranging from 1 to 10 in the case of FCF while 2 to 9 for PR dye. The pH of the solutions was maintained using NaOH and HCl of A.R. grade by pH meter, Model HI 8424 (M/s Henna Instruments, Italy).

### 3.1. Effect of sieve sizes and adsorbent dose

For the effect of sieve size three different mesh sizes were chosen viz. 36, 100 and 170 BSS mesh were exposed to know conc. of dye solutions for determining of the uptake capacities. Similarly the effect of the adsorbent dose was determined by considering 0.1 to 0.3 g of BA brought in contact with  $5 \times 10^{-5}$  M and pH = 2 solution of FCF and  $10 \times 10^{-5}$  M and pH = 7 solution of PR at 30, 40 and 50 °C.

### 3.2. Effect of concentration

*Adsorption* experiments were carried out using a concentration range of  $5 \times 10^{-6}$  to  $5 \times 10^{-5}$  M of aqueous solutions of FCF and  $1 \times 10^{-5}$  M to  $10 \times 10^{-5}$  M of PR with a fixed amount of BA (0.1g for FCF and PR). The data collected from this study was used for designing Langmuir isotherm.

### 3.3. Langmuir Isotherm:

Langmuir model [5-9] assumes adsorption to be monolayer and homogenous.

Below given is the mathematical expression:

$$\frac{1}{q_e} = \frac{1}{Q_0} + \frac{1}{bQ_0} \times \frac{1}{C_e} \quad (1)$$

Where,  $C_e$  is the molar concentration (M) in bulk–fluid phase,  $Q_0$  is number of moles of solute adsorbed per unit weight of adsorbent ( $\text{mol.g}^{-1}$ ),  $q_e$  is the number of moles of solute adsorbed per unit weight ( $\text{mol.g}^{-1}$ ) at concentration  $C$  and  $b$  is a constant related to the energy ( $\text{L.mol}^{-1}$ ). Thus plots between  $1/C_e$  versus  $1/q_e$  giving straight lines are used in the calculation of different thermodynamic parameters like Gibb's free energy ( $\Delta G^\circ$ ), change in enthalpy ( $\Delta H^\circ$ ) and change in entropy ( $\Delta S^\circ$ ) in the usual way.

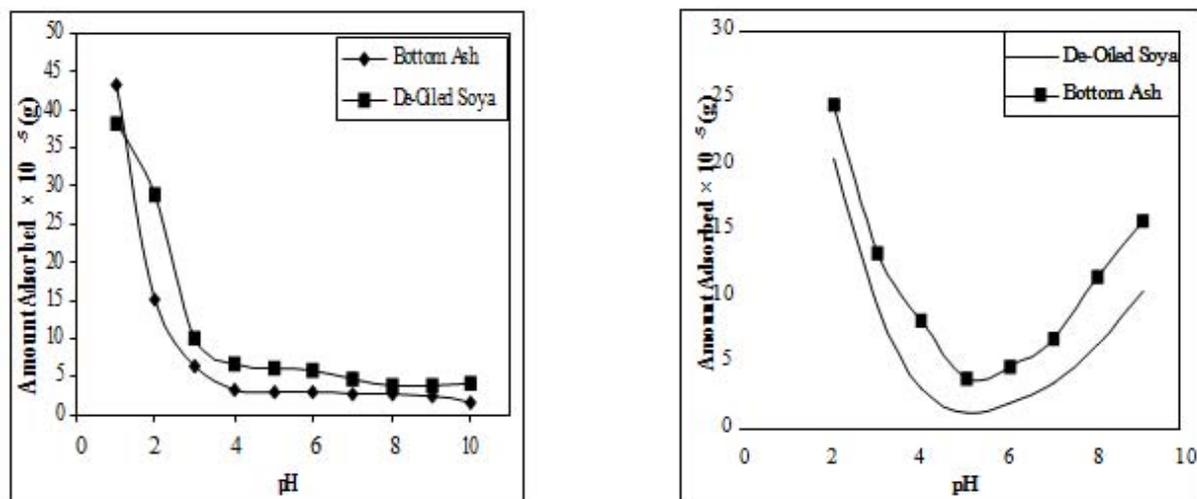
The negative values of Gibb's free energy ( $\Delta G^\circ$ ) indicate feasibility of the processes, while positive value suggests unfeasibility of the adsorption process. Similarly the exo/endothemic nature of the dye adsorption can be ascertained, in which a positive value would indicate the edothermic nature whereas a negative value the exothermic nature. The negative / positive values of entropy ( $\Delta S^\circ$ ) indicate the increase / decrease in the randomness of the process respectively.

## 4. Results and Discussions

### 4.1. Effect of pH:

For the dye FCF [10] with the increase in pH, adsorption was found to decrease till pH 4 in each and beyond pH 4, no significant difference in the amount of dye adsorbed was observed on proceeding further till pH 10 (Figure 1a). Thus all further studies were carried out at pH 2 due to its appreciable adsorption ability. In case of PR [11] dye, with the **increase** in pH adsorption was found to decrease till pH 5, after which the amount adsorbed was observed to increase till pH 9 (Figure 1b). For further studies pH 7 was chosen, as this pH gives high adsorption capacity in both the cases. In both the dyes adsorption initially decreases with the increase in the pH because protonation of the negatively charged adsorbents takes place at low pH thereby increasing the tendency of the adsorption of the anionic dyes over the adsorbent. This effect gradually decreases with the increase in pH hence decreasing the amount adsorbed.

Fig.1. (a) Effect of pH FCF; (b) Effect of pH PR



#### 4.2. Effect of sieve sizes and adsorbent dose

For both the dyes with the increase in the mesh sizes adsorption is found to decrease because of the availability of a *lesser* surface area. The amount of the dyes adsorbed was 16.20, 20.20, 36.40  $\times 10^{-5}$  (g) for FCF and 39.8, 46.9 and 54.0  $\times 10^{-5}$  (g) in the case of PR for 36, 100 and 170 BSS mesh respectively. With the increase in the amount of the adsorbent dose (Table 1) an increase in the amount of the dye adsorbed was registered. From 30-50 $^{\circ}$ C with the adsorbent dose ranging from 0.1-0.3g the amount of the dye adsorbed ranged from 8.08-61.0  $\times 10^{-5}$  (g) in case of FCF which was 43.5-51.1  $\times 10^{-5}$  (g) in case of PR dye.

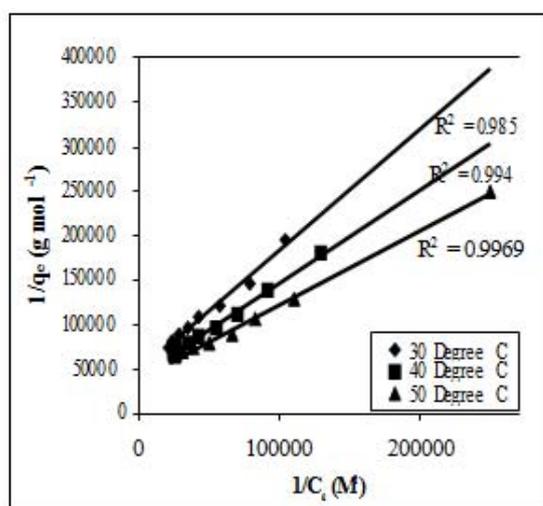
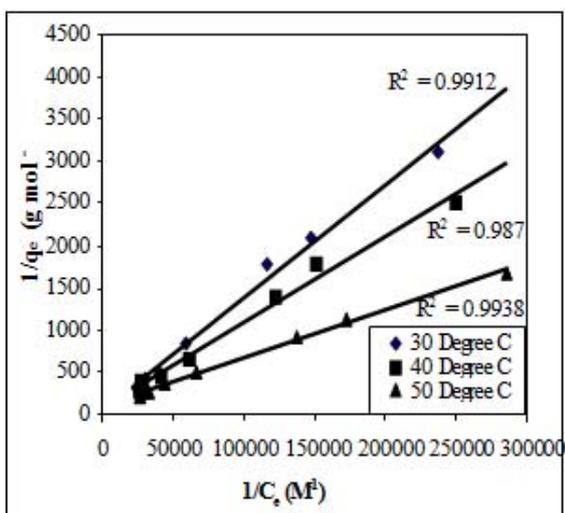
#### 4.3. Effect of concentration

Similar *trend* as in the case of effect of amount of adsorbent was noticed with the increase in the concentration *from* 30 to 50  $^{\circ}$ C and the study was extended in determining the thermodynamic parameters by Langmuir Isotherm.

#### 4.4. Langmuir Isotherms

The plots of Langmuir isotherm obtained for the two dyes have been shown (Figures 2a & b). The  $R^2$  values are obtained at all the temperatures; indicate the involvement of monolayer adsorption in both the dye adsorbent *systems*. The enthalpy values ( $\Delta H^0$ ) as shown in Table 2 show the adsorption process to be endothermic in both the cases (FCF & PR), however, the order being, PR > FCF.

Fig.2. (a): Langmuir Isotherm FCF; (b) Langmuir Isotherm PR



The values of *change* in entropy ( $\Delta S^\circ$ ) is of the order Phenol Red < Fast Green FCF for BA. The randomness in case of FCF (M.W. 808.85) is probably more than PR (M.W. 354.38) due to its greater molecular weight.

Table 1: Thermodynamic Parameters

| Dye | $-\Delta G^\circ$ (kJ.mol <sup>-1</sup> ) |       |       | $\Delta H^\circ$<br>(kJ.mol <sup>-1</sup> ) | $\Delta S^\circ$<br>(JK <sup>-1</sup> .mol <sup>-1</sup> ) |
|-----|---|-------|-------|---|--|
|     | 30 °C                                     | 40 °C | 50 °C |   |  |
| PR  | 26.32                                     | 27.53 | 28.83 | 190.9                                       | 88.6   |
| FCF | 20.15                                     | 23.01 | 26.45 | 74.70                                       | 312.35   |

## 5. Conclusion

FCF and PR adsorption over BA is found to be feasible as shown by the  $\Delta G^\circ$  values, endothermic and accompanied by increase in entropy. Therefore BA can be used as a potential adsorbent for the elimination of FCF and PR dyes.

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