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Investigation of Optimum Operating Parameters for BOD & COD Removal using Activated Carbon

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***Abstract*— This paper deals with the effect of Activated Carbon (AC) on adsorption of Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) of Sugar Industry wastewater using physical adsorption principle. Experimental investigation is carried out in batches by using AC prepared from Coconut Shell (IAC-C). Effect of various operating parameters such as Adsorbent Dose, pH, Treatment Time and Agitation Speed were investigated. The results are fitted to Langmuir and Freundlich isotherm models. The results of IAC-C studies revealed that it has higher efficiency in BOD and COD reduction and hence it can be used as an efficient adsorbent for treating sugar industrial effluent.**

***Keywords*—BOD, COD, IAC-C, Langmuir and Freundlich Adsorption Isotherms.**

I. INTRODUCTION

Effluents from sugar industries induce environmental pollution. India, being one of the major producers of sugar in the world, is prone to large volume of wastes from sugar industries. The byproducts namely bagasse, molasses, distillery wastes and press mud are some of the major objectionable wastes generated by the sugar industries contributing to high BOD and COD [1].

Activated carbon is one of the major adsorbents used for treatment of sugar industry wastes to reduce BOD and COD [2, 3]. Ideal adsorbents must obey the following characteristics; a solid, with high surface area, high porosity, inertness and stability to withstand chemical, thermal and climatic changes, cost effective and good physicochemical properties similar to that of commercial activated carbon. An adsorbent possessing the above properties, would be considered as a good adsorbent in water and wastewater treatments [4, 5].

Many researches have been done to identify a low cost substitute for activated carbon for the treatment of industrial effluents to reduce BOD and COD. The low-cost adsorbents can be viable alternatives to activated carbon for the treatment of wastewater. It is important to note that the adsorption capacities may vary, depending on the characteristics of the individual adsorbent, surface modification and the initial concentration of the adsorbate.

In general, technical applicability and cost effectiveness are the key factors that play major roles in the selection of the most suitable adsorbent to treat effluent.

Further, it has been reported activated carbon prepared from tamarind nut, metakaolin, and date nut [1], pecan shell based [5], bamboo and bamboo waste [6], bael tree leaf powder [7], coconut shell and coconut bunch waste [8, 9, 10 and 11], wood ash and bagasse pith [12], cocoa shell [13], and date-pit [14] could be used as possible absorbents to treat the effluents for reduction of BOD and COD with high efficacy.

Further, use of absorbents for BOD and COD reduction has the advantage of easy sludge disposal when compared to conventional precipitation technique. In the present study coconut shell activated carbon which are belonging to low cost category, have been investigated as the possible adsorbents for the reduction of BOD and COD from sugar industry effluents. Several parameters like adsorbent dosage, pH, contact time and agitation speed were optimized.

II. MATERIALS AND METHODOLOGY

The physical adsorption is one of the new removal mechanisms in the adsorption method. In this the adsorbate adheres on the surface of adsorbent only through Van der Waals (weak intermolecular) interactions.

A. Materials

Wastewater samples were collected from a local sugar industry named Sanjivani Sahakari Sakhar Kharkhana Ltd., Shahjanandanagar, Sanjivani, Kopargaon. The sample was collected from the discharge channel outlets of sugar industry and stored at 2-3^{0}C. The initial characteristics of the sample were analyzed according to the standard procedure given in Guide Manual for Water and Wastewater Analysis by CPCB [15] and are listed in Table 1. Activated carbon used in the present study is Commercial AC and is directly purchased from local traders, 'Fortitude Enviro Team'. The raw materials used in the adsorbents for the present study is coconut shell.

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The important characteristics of commercial activated carbon prescribed by the manufacturer were: surface area $0.9x10^6$ m^3/kg, particle density 175 kg/m^3, Iodine value of 1000 and moisture content was 5.8%.

Table 1
Physico-Chemical Properties Of Sugar Industry Wastewater.

Sr. No.	Parameters	Characteristic Value
1	Colour	Greenish Grey
2	pH	10.2
3	Temperature	36^0C
4	DO	Absent
5	BOD	2515 mg/l
6	COD	6820 mg/l
7	Alkalinity	930 mg/l
8	Dissolved Solids	2382 mg/l
9	Chlorides	580 mg/l

B. Methodology

The colour, pH and temperature of the wastewater samples were measured on collection site. BOD and COD were analyzed in laboratory according to the methods prescribed in Guide Manual for Water and Wastewater Analysis by CPCB. Titrimetric method is used for analysis of BOD and Open Reflux method is used for the analysis of COD. The BOD and COD of the wastewater samples were measured in laboratory before and after treatment with the adsorbents.

C. Batch Mode Treatment of Wastewater Samples

All the experiments were carried out at ambient temperature (25^0C) in batch mode. The batch experiments were run in different flasks of 500 ml capacity using an average speed shaker. Adsorption experiments were conducted in different batches for the adsorbents, where the adsorbent dose, pH of the solution, adsorbent treatment time and agitation speed were changed for the different sets of experiments.

D. Operating Parameters

The influence of various operating parameters was studied by varying one parameter and keeping the others constant. Stirring speed of the shaker was kept constant for each run throughout the experiment, ensuring equal mixing, except for those, which were meant for investigating the effect of agitation speed. The desired pH was maintained using NaOH (0.1N) and HCL (0.1N) solutions. Each flask was filled with a known volume of sample having desired pH and stirring was started.

The sample was withdrawn from the shaker at predetermined time intervals, filtered through Whatmann No. 44 filter paper and analyzed for BOD and COD.

E. Adsorbent Dose

To determine the contribution of the adsorbent dose to BOD and COD reduction, 100 ml of sample was treated with different doses of adsorbent ranging between 0.5 to 7 gm/100ml., the other conditions includes, initial BOD concentration: 2515mg/l, initial COD concentration: 6820 mg/l, treatment time: 180 min, pH 4 and 3 for BOD and COD resp. and agitation speed: 600 rpm. The samples were agitated for specific time interval of 180 min., filtered and then analyzed for the residual BOD and COD concentration.

F. pH

The pH study was performed by varying the pH values from 1 to 12 using HCl and NaOH solutions. Initial BOD concentration: 2515 mg/l, initial COD concentration: 6820 mg/l, adsorbent dose: 3.5gm/100ml and agitation speed: 600 rpm. The samples were agitated for specific time interval of 180 min., filtered and then analyzed for residual BOD and COD concentration.

G. Adsorbent Treatment Time

Effect of contact time (adsorbent treatment time) of the adsorbents with wastewater sample was investigated by agitating 100 ml sample and adding 3.5 gm adsorbent for different time periods varying between 30 to 300 min. Initial BOD concentration: 2515 mg/l, initial COD concentration: 6820 mg/l, adsorbent dose: 3.5 gm/100ml, pH: 4 and 3 for BOD and COD, agitation speed: 600 rpm. The treated samples were withdrawn from shaker at predetermined time intervals, filtered and the residual BOD and COD concentrations were measured.

H. Agitation Speed

The effect of agitation speed on percentage BOD and COD removal was investigated by keeping the agitation speed between 100 rpm to 900 rpm. Initial BOD concentration: 2515 mg/l, initial COD concentration: 6820 mg/l, treatment time: 180 min, adsorbent dose: 3.5 gm/100ml and pH: 4 and 3 for BOD and COD. The samples were agitated for different agitation speed, filtered and then analyzed for the residual BOD and COD concentration.

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I. Langmuir Isotherm Model

The adsorption data is analyzed according to a linear eq. of Langmuir Isotherm Model [16, 17] as follows.

$$\frac{1}{q_e} = \frac{1}{Q_o k_L} \frac{1}{C_e} + \frac{1}{Q_o}$$

where,

q_e = amount of adsorbate in the adsorbent at equilibrium i.e. amount of BOD and COD removed/adsorbed per unit mass of adsorbent (mg/g)

C_e = equilibrium concentration (mg/L)

Q_o = maximum monolayer coverage/adsorption capacity i.e. maximum amount of BOD and COD adsorbed per unit mass of adsorbent to form a complete monolayer on the surface (mg/g)

k_L = Langmuir isotherm constant related to the affinity of the binding sites (L/mg)

For Langmuir isotherm model, a plot of $\left(\frac{1}{q_e}\right)$ vs. $\left(\frac{1}{C_e}\right)$ is employed. A linear equation is used to generate the values of constants (Q_o) and (k_L) and coefficient of regression.

J. Freundlich Isotherm Model

The adsorption data is analyzed according to a linear eq. of Freundlich Isotherm Model [16, 17] as follows.

$$\log q_e = \frac{1}{n} \log C_e + \log k_F$$

Where,

q_e = amount of adsorbate in the adsorbent at equilibrium (mg/g)

C_e = equilibrium concentration (mg/L)

k_F = Freundlich isotherm constant (mg/g) $(dm^3/g)^{1/n}$ related to adsorption capacity of the adsorbent

n = indicates favorability of adsorption i.e. if n>1 it indicates favorable adsorption condition

For Freundlich isotherm model, a plot of $(\log q_e)$ vs. $(\log C_e)$ is employed. A linear equation is used to generate the values of constants $\left(\frac{1}{n}\right)$ and (k_F) and coefficient of regression.

III. Results And Discussion

The wastewater was treated under batch mode operation using IAC-C and BOD and COD concentrations were measured before and after treatment with the adsorbent. The important operating parameters taken into consideration for the present study are time adsorbent dose, pH of the medium, adsorbent treatment and agitation speed.

A. Adsorbent Dose

A study was done on the effect of adsorbent dose on percentage reduction of COD and BOD with coconut based activated carbon (IAC-C) as shown in fig. 1. Equilibrium was reached corresponding to 3.5 gm/100ml adsorbent dose for the optimum percentage reduction of 98.27% in BOD and 98.77% in COD. After equilibrium, further addition of adsorbent results in constant removal of BOD and COD. Initial BOD concentration: 2515 mg/l, initial COD concentration: 6820 mg/l, treatment time: 180 min, pH 4 and 3 for BOD and COD and agitation speed: 600 rpm.

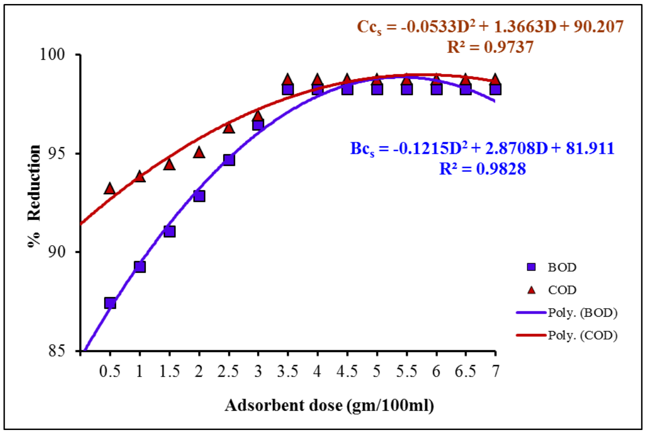

Fig. 1: Effect of adsorbent dose on percentage BOD and COD reduction by IAC-C

B. pH

The effect of pH on the BOD and COD reduction from wastewater is shown in fig. 2. It was clear that IAC-C shows better adsorption at pH 4 and 3 for BOD and COD resp. with 98.27% in BOD and 96.31% in COD. The reason for better adsorption capacity observed at lower pH levels might be attributed to the presence of larger number of H^+ ions. The reduction in adsorption at higher pH, on the other hand, might be possible due to the abundance of OH^- ions, causing increased hindrance to the diffusion of organic (contributing to COD) ions. Initial BOD concentration: 2515 mg/l, initial COD concentration: 6820 mg/l, treatment time: 180 min., adsorbent dose 3.5 gm/100ml and agitation speed: 600 rpm.

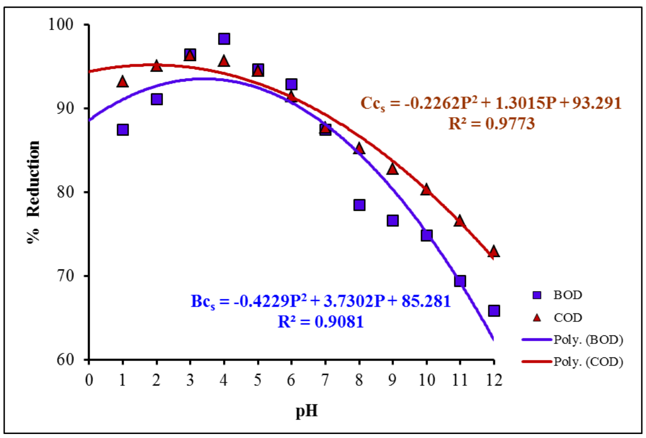

Fig. 2: Effect of pH on percentage BOD and COD reduction by IAC-C

C. Adsorbent Treatment Time

The absorption increases with increase in time and reaches saturation according to its capability. Effect of percentage BOD and COD reduction was studied as a function of treatment time with coconut shell activated carbon (IAC-C) as shown in fig. 3. The optimum percentage reduction of BOD and COD was 96.47% and 92.61% respectively after a treatment time of 180 min. As the treatment time progressed, the adsorbent sites had the tendency towards saturation. Initial BOD concentration: 2515 mg/l, initial COD concentration: 6820 mg/l, adsorbent dose: 3.5 gm/100ml, pH: 4 and 3 for BOD and COD resp., agitation speed: 600 rpm.

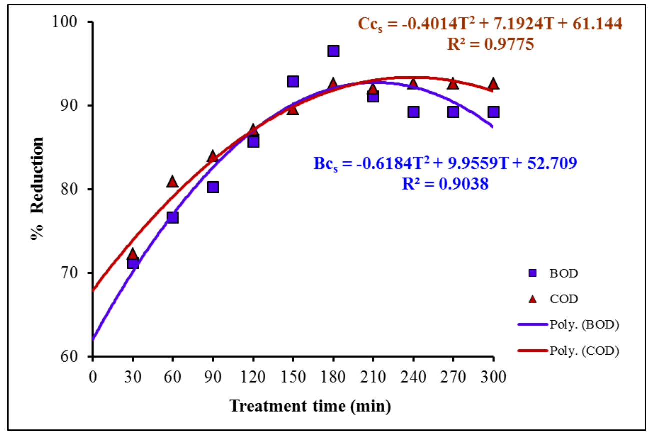

Fig. 3: Effect of treatment time on percentage BOD and COD reduction by IAC-C

D. Agitation Speed

To investigate the effect of agitation speed on percentage BOD and COD reduction with IAC-C the agitation speed was kept between 100 rpm to 900 rpm. Fig. 4 showed that there was a very slow trend for the percentage BOD and COD reduction. Maximum BOD and COD reduction of 91.05% and 87.69% respectively was observed around 600 rpm for IAC-C. But at higher agitation speeds, the loosely attached molecules might re-enter into the adsorbate, lowering the percentage BOD and percentage COD reduction. Therefore we kept the agitation speed at 600 rpm. Initial BOD concentration: 2515 mg/l, initial COD concentration: 6820 mg/l, treatment time: 180 min, adsorbent dose: 3.5 gm/100ml and pH: 4 and 3 for BOD and COD resp.

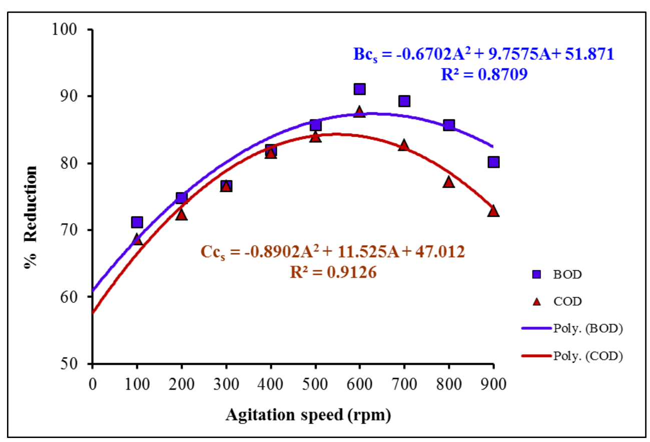

Fig. 4: Effect of agitation speed on percentage BOD and COD reduction by IAC-C

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E. Langmuir Isotherm Model

From the Langmuir isotherm model as shown in fig. 5 and fig. 6 for BOD and COD resp., constants obtained are: $\left(Q_O\right)$ is 0.2769 and 0.9109 for BOD and COD resp. while $\left(k_L\right)$ is 5.9484 and 2.2976 for BOD and COD resp. The regression coefficient is 0.8576 and 08293 for BOD and COD resp.

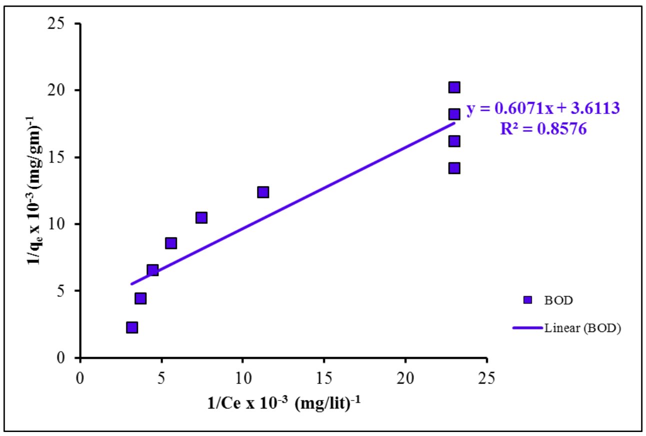

Fig. 5: Langmuir Isotherm Model for BOD

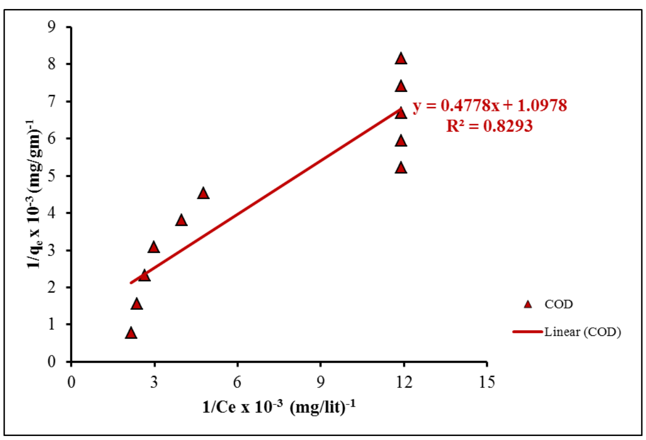

Fig. 6: Langmuir Isotherm Model for COD

F. Freundlich Isotherm Model

From the Freundlich isotherm model as shown in fig. 7 and fig. 8 for BOD and COD resp., constants obtained are: $\left(\frac{1}{n}\right)$ is 0.8544 and 0.9399 for BOD and COD resp. while $\left(k_F\right)$ is 1.8578 and 1.9597 for BOD and COD resp.

The regression coefficient is 0.8687 and 0.8268 for BOD and COD resp. Here the value of *n* is greater than one for both BOD and COD which indicates favourable adsorption.

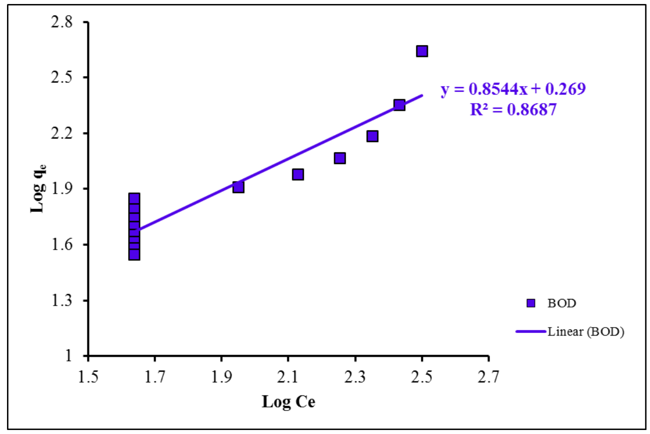

Fig. 7: Freundlich Isotherm Model for BOD

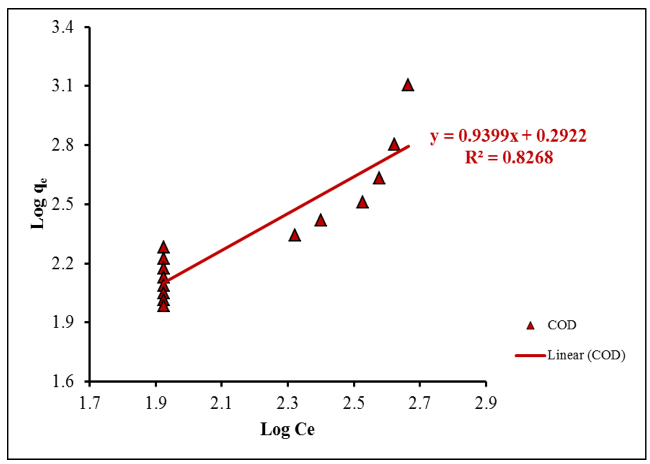

Fig. 8: Freundlich Isotherm Model for COD

IV. CONCLUSION

This study shows that IAC-C has good efficiency in BOD and COD reduction of sugar industry wastewater. The effect of various parameters such as adsorbent dose, pH, adsorbent treatment time and agitation speed showed a significant variation in percentage removal efficiencies of BOD and COD. The optimum operating parameters for maximum BOD and COD reduction are, Adsorbent dose: 3.5gm/100ml of sample, pH: 4 and 3 for Bod and COD resp., Treatment time: 180 min. and Agitation speed: 600 rpm.

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The regression coefficient of Langmuir isotherm models are 0.8576 and 08293 for BOD and COD resp., and regression coefficient of Freundlich isotherm models are 0.8687 and 0.8268 for BOD and COD resp. Hence, Freundlich isotherm model is the best fit for BOD adsorption and Langmuir isotherm model is the best fit for COD adsorption. Also from Freundlich isotherm model the value of n is greater than one for both BOD and COD which indicates favourable adsorption. Therefore, it can be concluded that coconut shell activated carbon could be used as an efficient adsorbent in treating sugar industrial wastewater for BOD and COD reduction.

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