



## The effect of Powdered Activated Carbon (PAC) to the removal of cod content of sugar industry waste water

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### ABSTRACT

Rapid globalization lead us on the way to industrialization. Sugar industry is one of the biggest consumer of water, and can also introduce serious pollutant to the environment. Chemical as well as biological treatment to these waste waters are in practice since long. Powdered Activated Carbon (PAC) prepared from wood and nutshell charcoal with specific surface area of 5602.352 cm<sup>2</sup>/gm and particle size 44  $\mu$  m is used as an adsorbent to the combined waste water of Sugar mill at room temperature. The different dosage of PAC is kept in contact for 24 hours, then they will analyzed before and after treatment. The results of COD removal follow the Freundlich and Langmuir adsorption isotherm.

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### Introduction

Water is one of the essential enablers of life on earth. But pure water is not available to a large fraction of the population of the planet. While availability is an issue, contamination is another major concern which threatens the survival of many<sup>1</sup>. The Sugar Industry in India is one of the oldest and largest industry in the country. These mills require large volume of water of high purity and generate equally large volume of waste water which is highly complex and polluted<sup>2</sup>. In the present study, it was aimed to carry out experiments using Powdered Activated Carbon for the removal of organic contaminants especially COD contributing components from the combined waste water of Sugar Industry, which is situated in South Gujarat region of India.

For removal of the organic contaminants from industrial waste water adsorption has become one of the best effective and economical method, thus this process has aroused considerable interest during recent years. Current research has focused on modified or innovative approach that more adequately address the removal of organic pollutants<sup>3</sup>. Adsorption of various substances onto carbon surface is an exceedingly complex process to solve the water quality problem has been discussed thoroughly<sup>4</sup>. A novel Freundlich type multi-components adsorption isotherm was employed successfully to describe the adsorption of organic pollutants on activated carbon from the multi-component aqueous solution<sup>5</sup>. Various activated carbons were tested for its better quality and quantity of different particle size for a comparison of its adsorption characteristics<sup>6</sup>. Rates of adsorption increases with the reduction in particle size and it is inversely proportional to the square of the carbon particle diameter<sup>7</sup>. Adsorption is a water treatment process that removes a soluble substance from the water. As carbon adsorption method is effective in removing pollutants.

The flocculation—adsorption process showed good performance in removing the chemical oxygen demand 86% at a

FeCl<sub>3</sub> concentration of 40 mg/l, and powdered activated carbon concentration of 20 mg/l<sup>8</sup>. Removal of COD contributing components, TOC and cadmium of the waste water by adsorption process on fly ash and PAC was well studied. The data follow Freundlich and Langmuir type behavior. The reaction rate was evaluated for different time intervals and at different pH<sup>9</sup>.

The removal of humic acids and phenol from model solution by coagulation and adsorption on powdered activated carbon (PAC) was investigated. A PAX XL-69 polyaluminum chloride was applied as a coagulant. The adsorption of humic acids and phenol on activated carbon for single- and bi-component solutions was studied. It was found that coagulation without PAC addition was less effective than the adsorption-coagulation integrated system<sup>10</sup>. Some researchers studied on adsorption characteristics of Congo red on coal-based mesoporous activated carbon. He found the monolayer adsorption capacity of ACs was found to increase with increasing both the mesoporous volume and the mesoporous contribution to their porous texture. They derived a correlation between the Langmuir adsorption capacity and the degree of mesopore development. The higher the both mesopore volume and mesopore contribution to the total pore volume, the higher is the adsorption capacity of the activated carbon with respect to Congo red dye<sup>11</sup>. The adsorption characteristics of Congo red dye differs for PAC and GAC. The result by using Taguchi method may be summarized as 1. From S/N ratio of PAC the influencing parameters are in the order temperature > pH > Contact time. 2. Similarly for GAC the influencing parameters are in order pH > contact time > temperature. The optimum condition for adsorption CR dye on PAC is found to be pH of 2, temperature 50°C, contact time 300 minutes. But for GAC, Taguchi method optimizes the adsorption at pH-2, temperature 60°C and time-300 minutes<sup>12</sup>. An experimental investigation carried out on a pilot scale membrane bioreactor (MBR) with the

addition of powdered activated carbon (PAC) to analyze improvements in effluent quality and in the filtration process. The results refer COD removal stability appeared to increase as PAC concentration increased. No effects were observed on the nitrification processes. The filtration process was evaluated in terms of sludge filterability, fouling rate and fouling reversibility. The fouling rate decreased with an increasing PAC concentration and showed complete reversibility both in presence and in absence of PAC<sup>13</sup>. In the Fenton oxidation reaction at pH 3, when PAC was added to the pre-treated supernatant, the COD removal efficiency was 80.22%. When UF membrane separation was performed using this specimen, COD removal efficiency is 98.48%. When the membrane separation was undertaken without PAC the COD removal efficiency is 94.93%. Thus, the COD removal efficiency was higher when PAC was added compared with that observed when PAC was not added<sup>14</sup>.

#### Material and Method:

Powdered Activated Carbon (PAC) with specific surface area 5602.352 cm<sup>2</sup>/gm and particle size 44 μ m was used as an adsorbent for the treatment of sugar industry waste water. For present research work the adsorbent sample was prepared from wood and nutshell charcoal. The process of manufacturing of activated carbon included carbonization followed by activation. Wherein on pyrolysis of raw materials polynuclear aromatic system get resulted. The carbon formed would be further activated by burning it in atmosphere of CO<sub>2</sub>, CO, O<sub>2</sub>, H<sub>2</sub>O vapour, air or other selected gases at temperature between 300 to 1000<sup>0</sup> C.

These activated carbons were added to sugar industry waste water sample and the mixture was stirred well and was kept in contact until equilibrium state attain and that was 24 hours for this system. The known quantity (1 liter) of sample was treated with different amount of Powdered Activated Carbon viz 1, 2, 5, 10, 15, 20, 30 gm/L stirred well and kept in contact for 24 hours at room temperature. Then the samples were filtered and analyzed for various physico-chemical characteristics. This study was especially concentrated on COD removal. The method for determination of COD practicable is dichromate reflux method followed from 'Standard methods for the water and waste water'<sup>15</sup>. The results for each dose are presented in **Table 1, 2** and **figure 1, 2**.

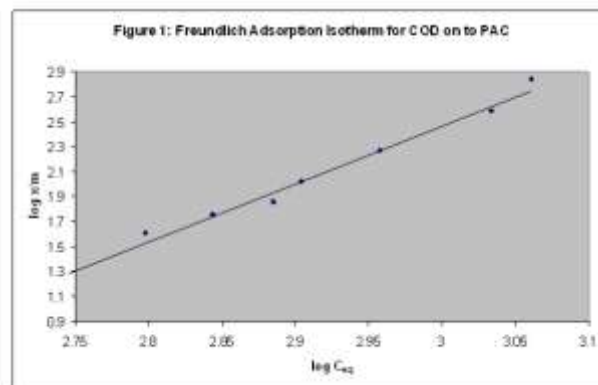
#### Results and discussion:

**Table 1** shows the influence of dose variation of Powdered Activated Carbon onto various physico-chemical characteristics of the combined waste water of Sugar Industry at room temperature. The pH of the untreated sample is 5.68 which increase upto 7.62 with increasing dose of PAC upto 30 gm/L. The conductance increased from 1.737 m mho (initial) to 2.43 with 30 gm/L of PAC concentration. The initial COD content of the waste water was 1847.58 mg/L which is suddenly reduced to 1150.38 mg/L with 30gm/L of PAC. The BOD content of the waste water was 917.6 mg/L is reduced to 62 mg/L by 20gm/L of PAC and remain constant for higher doses. The alkalinity of the sample is 1020 mg/L is first dropped to 620 mg/L at the dose of 1 gm/L and 2 gm/L and then increase upto 900 mg/L with increasing amount of PAC. The chloride content is not affected at any concentration of PAC.

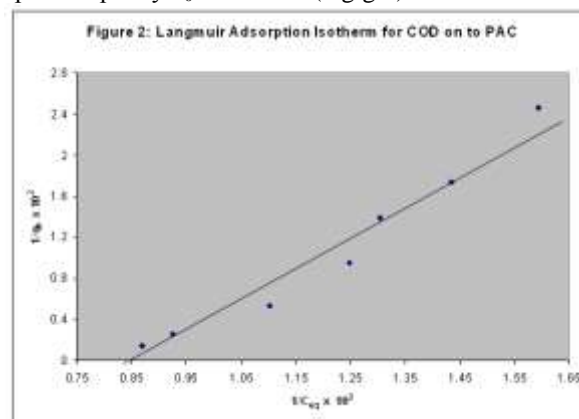
Table 2 represents the data for Freundlich and Langmuir adsorption isotherms along with percent removal of COD exerting components of sugar industry waste water on to PAC. It can be observed that the percent removal of COD increases with

increase in PAC concentration from 37.73% to 66.04%. The removal per unit weight is found to be decreased from 697.2 mg/gm to 40.67 mg/gm with increase in PAC dose. The logarithmic values of equilibrium concentration (C<sub>eq</sub>) and removal per unit weight (x/m) were given in table which were used for the explanation of Freundlich adsorption isotherm model and plot whereas the inverse values needed for Langmuir isotherm model.

**Figure 1** represents the plot of log C<sub>eq</sub> Vs log x/m (COD) for fly PAC. The straight line nature of the plot corresponds to slope 1/n and intercept K. 1/n is related to adsorption intensity whose value is 4.0445 for COD while intercept K on Y-axis related to adsorption capacity is found to be 1.2



**Figure 2** represents the plot of Langmuir parameters viz, 1/C<sub>eq</sub> x 10<sup>3</sup> and 1/q<sub>e</sub> x 10<sup>3</sup>. The nature of the curve for COD onto PAC is linear however the intercept on X-axis related to adsorption energy (L/mg) i.e. b x 10<sup>3</sup> is 0.84 L/mg for COD exerting components. These values can be used to calculate the adsorption capacity θ<sub>0</sub> i.e 282.84 (mg/gm).



Influence of different dose of PAC on various physico-chemical characteristics can be explained as the pH increases with increasing amount of PAC dose can be linked with removal of components contributing to acidic character of the waste water sample, similar conclusion can be drawn for increasing removal of alkalinity.

The first dropping and then increasing trend can be explained as the PAC particle itself contribute some inorganic matter into the waste water for alkalinity and conductance, because after treatment of PAC the conductance of the waste water is seems to be increased also suggest the increasing amount of ionic species. At lower concentration of PAC the hardness causing contaminants can be removed from the waste water which is not affected much more and remains constant for higher doses. The results for COD clearly establishes the removal of COD contributors can be explained on the basis of

adsorption phenomenon and the extent can be co-related with increasing adsorption sites with increase in the dose, the similar adsorption phenomenon occurs for the removal of BOD causing contaminants. It is evident that the presence of the PAC sites has no effect on initial chloride content of the waste water sample.

**Table 2** represents the data for Freundlich and Langmuir adsorption isotherms along with percent removal for COD onto PAC. These information are used to prove the adsorption isotherm model and from that the Adsorption intensity, Adsorption energy and Adsorption capacity can be calculated. The percent removal of COD seems to be increased with increase in dose of adsorbent. The logarithmic and inverse values of  $C_{eq}$  and  $x/m$  are used for plot of isotherm.

The logarithmic value of equilibrium concentration and removal per unit weight gives the linear plot for COD by PAC confirm the applicability of Freundlich adsorption isotherm. It is the most widely used mathematical description of adsorption in aqueous systems. The equation is an empirical expression that covers the heterogeneity of the surface and exponential distribution of sites and their energies. With the purpose of linearization the equation is represented in logarithmic form as—

$$\log x/m = \log K + 1/n \log C_{eq}$$

The plot of  $\log C_{eq}$  versus  $\log x/m$  gives straight line with a slope of  $1/n$  and  $\log K$  is the intercept of  $\log x/m$  at  $\log C_{eq} = 0$  which indicates that Freundlich adsorption isotherm model is applicable.

The same table shows the Langmuir adsorption isotherm for COD by PAC. Langmuir isotherm is a plot of the amount of impurity adsorbed by PAC against the amount of impurity that remains in solution. It is a preliminary test to check the efficiency of particular material.

These mode of action can be explained on the basis of Langmuir's model, i.e. 'Ideal localized monolayer model' according to which:

1. The molecules are adsorbed at definite sites on the surface of the adsorbent.
2. Each site can accommodate only one molecule (monolayer).
3. The area of each site is a fixed quantity determine solely by the geometry of the surface.
4. The adsorption energy is the same at all the sites.

Such behavior on the basis of kinetic consideration, presuming that the adsorbed molecules cannot migrate across the surface of the interact with another neighboring molecules can be mathematically expressed as under

$$1/q_e = 1/\theta_0 b \times 1/C_{eq} + 1/\theta_0$$

Where-

$q_e$  = amount of solute adsorbed per unit weight of adsorbent (mg/gm)

=  $x/m$  i.e.  $x$  is amount of adsorbate adsorbed(mg/L)  $m$  is weight of adsorbent (gm/L)

$C_{eq}$  = equilibrium concentration of the solute (mg/L)

$\theta_0$  = Langmuir constant related to adsorption capacity (mg/gm)

$b$  = Langmuir constant related to adsorption energy (L/mg)

Plot of  $\log C_{eq}$  versus  $\log x/m$  is a straight line in nature, presented in figure 1 suggests the applicability of this isotherm and indicate a monolayer coverage of the adsorbate on the outer surface of the adsorbent. The steep slope indicates high adsorptive intensity at high equilibrium concentration that rapidly diminished at lower equilibrium concentration covered by the isotherm. As Freundlich equation indicates the adsorptive capacity  $x/m$  is a function of the equilibrium concentration of

the solute. Therefore, higher capacity is obtained at higher equilibrium concentrations.

Figure 2 represents the plot of Langmuir adsorption isotherm for COD contributing components onto PAC. The straight line nature of the plot confirms the applicability of the Langmuir model and also the monolayer coverage. The Langmuir constant  $\theta_0$  in mg/gm related to adsorption capacity indicate availability of more surface active region onto adsorbent site and  $b \times 10^3$  L/mg related to adsorption energy in terms of  $x/m$  is a characteristic of the system.

### Conclusion

This study leads us to the conclusion that the final combined waste water of Sugar manufacturing unit is highly polluted having higher COD value. Due to some practical limitation only COD parameter is emphasized in this paper when the final combined waste water of Sugar mill is treated with finely divided low cost material PAC at room temperature for 24 hours of contact duration the following results are achieved.

- i. The maximum COD removal is found at 30gm/L of PAC concentration i.e. 66.04%
- ii. Just 20 gm/L Powdered Activated Carbon removes BOD contributing components of the waste water up to 93.24%
- iii. The chloride content of the sample do not affected at all with increasing amount of PAC.
- iv. At room temperature PAC works as an adsorbent and follow Freundlich and Langmuir isotherm models. The results give straight line which confirms the applicability of isotherm.
  - a. The Freundlich constant  $K$  an intercept on X axis is related to adsorption capacity is found to be 1.3 while the slope  $1/n$  is related to adsorption intensity is found to be 4.0445
  - b. The straight line of the Langmuir plot gives intercept on Y axis called  $b \times 10^3$  L/mg i.e. adsorption energy is 0.84 and the calculated adsorption capacity  $\theta_0$  mg/gm is 282.85

### Conclusion

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**Table 1**The influence of dosage variation of Powdered Activated Carbon (PAC) on various physico-chemical characteristic of Sugar Industry Waste Water  
**Adsorbent: Powdered Activated Carbon (PAC) Room temperature: 26± 1<sup>0</sup>C Specific Surface Area: 5802.352 cm<sup>2</sup>/ gm Contact duration: 24 Hours Particle size: 44 μ m**

Parameter	Untreated Sample	1 gm/L	2 gm/L	5 gm/L	10 gm/L	15 gm/L	20 gm/L	30 gm/L
pH	5.68	6.94	7.17	7.17	7.17	7.23	7.27	7.62
Conductance (m mho)	1.737	1.54	1.7	1.784	1.91	2.12	2.13	2.43
COD (mg/L)	1847.58	1150.38	1080.66	906.36	801.78	766.92	697.2	627.48
BOD (mg/L)	917.6	229.4	186	124	93	86.8	62	62
Alkalinity (mg/L)	1020	620	620	650	800	850	900	900
Hardness (mg/L)	850	700	600	600	600	600	600	600
Chloride (mg/L)	137.457	137.457	137.457	137.457	137.457	137.457	137.457	137.457

**Table 2**Freundlich and Langmuir adsorption isotherm parameters for COD contributing components and percent removal of COD in presence of PAC  
**Adsorbent: Powdered Activated Carbon (PAC) Room temperature: 26± 1<sup>0</sup>C Specific Surface Area: 5802.352 cm<sup>2</sup>/ gm Contact duration: 24 Hours Particle size: 44 μ m**

No	Adsorbent conc. m (gm/L)	Eq. Conc. C <sub>eq</sub> (mg/L)	Removal x= C <sub>0</sub> -C <sub>eq</sub> (mg/L)	q <sub>e</sub> = x/m (mg/gm)	Removal %	Log C <sub>eq</sub>	log x/m	1/C <sub>eq</sub> x10 <sup>3</sup>	1/q <sub>e</sub> x10 <sup>2</sup>
1	0	1847.58	-----	-----	-----	3.2666	-----	0.5412	-----
2	1	1150.38	697.2	697.2	37.73	3.0608	2.8434	0.8693	0.1434
3	2	1080.66	766.92	383.46	41.51	3.0337	2.5837	0.9254	0.2608
4	5	906.36	941.22	188.244	50.94	2.9573	2.2747	1.1033	0.5312
5	10	801.78	1045.8	104.58	56.6	2.9041	2.0194	1.2472	0.9562
6	15	766.92	1080.66	72.044	58.49	2.8848	1.8576	1.3039	1.3880
7	20	697.2	1150.38	57.519	62.26	2.8434	1.7598	1.4343	1.7386
8	30	627.48	1220.1	40.67	66.04	2.7976	1.6093	1.5937	2.4588