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Adsorption study of BOD content from Sugar Industry waste water by low cost material Fly ash

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ABSTRACT

The problem of water pollution can only be minimize by clarify the industrial waste water at the place of its generation point by some chemical or biological treatment method. During present study the low cost material fly ash i.e. the waste of thermal power station which itself produce pollution of environment is used for purpose of water pollution control. Fly ash with specific surface area of 6177.15cm^2/gm is used as a clarifier to the combined waste water of Sugar mill at room temperature. The different dosage of fly ash is kept in contact for 24 hours and analyzed before and after treatment. Fly ash of the thermal power station removes 20.88% BOD contributing components of the waste water. At room temperature fly ash works as an adsorbent and follow Freundlich and Langmuir isotherm models. The straight line nature confirms the applicability of isotherm. The Freundlich constant K an intercept on X- axis is related to adsorption capacity is found to be 0.25 while the slope 1/n is related to adsorption intensity is found to be 11.4454. The straight line of the Langmuir plot gives intercept on Y- axis called b x 10^3 L/mg i.e. adsorption energy is 0.7510 and the calculated adsorption capacity θ_0 mg/gm is 9.

Key words: Fly ash, Adsorption, BOD, Adsorption isotherm, Adsorption intensity (1/n), Adsorption energy (b x 10^3), Adsorption capacity (K, θ_0).

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 [1]. 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 [2]. The conventional wastewater treatment technologies as adopted in industrialized nations are expensive to build, operate and maintain. The main objective of one of the study group was to develop low cost and effective wastewater treatment technology for the reduction of COD and BOD from wastewater using activated sludge, sand filter, activated carbon and chlorination [3]. 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 [4]. The activated carbon adsorbent prepared from pod of wood apple [5], Alternanthera Bettzichiana (Regel) Nicols plant material [6] and neem leaf powder [7] can be used as an efficient low cost adsorbent for Cr (VI) and organics removal from aqueous solution. Coal fly ash, the solid waste of the power plants has been used as an adsorbent for the removal of cadmium from the aqueous solutions. Removal of

Cr(VI) and Hg(II) from waste water by adsorption on fly ash was studied by Banerjee et al. Applicability of Freundlich adsorption isotherm was confirmed for all [8-11]. Study deals with the experimental investigations carried out on monitoring and treatment of effluents from hydrogenerated vegetable oil industry. The effluents contained high values of BOD, COD and oil and grease. The treatment of effluent in a composite column containing fly ash, activated carbon and lime and found to be reduce BOD by 97%, COD by 95.1% and oil and grease by 99%. The treatment technique is not only feasible but also economically viable [12].

In the present study, it was aimed to carry out experiments using low cost material like fly ash from thermal power station for the removal of organic contaminants especially BOD contributing components from the combined waste water of Sugar Industry. The laboratory scale studies for reduction of concentration of phenolic compound and COD content with fly ash is carried out and its adsorption characteristics were well explained [13-14]. The use of fly ash for the removal of color from waste water of petrochemical industry was done. Some research workers studied various variables like fly ash dose, contact time, pH of the effluent and color intensity [15]. Removal of COD contributing components, TOC and cadmium of the waste water by adsorption process on fly ash was well studied. The data follow Freundlich and Langmuir type behavior. The reaction rate was evaluated for different time intervals and at different pH [16]. Isotherm data were presented for the sorption of 20 organic compounds including alcohols, ketones and aldehydes by fly ash [17]. Fly ash can be used as a promising adsorbent for removal of various types of pollutants from wastewater. Low-cost adsorbents of different origin like industrial waste material, bagasse fly ash and jute-processing waste can also be used for removal of organic matter from wastewater [18-19].

MATERIALS AND METHODS

In modern thermal power station pulverized coal is used and fly ash is obtained as a waste product in large quantities. Fly ash is also known as pulverized fuel ash. The source of fly ash material used in present research work is from Ukai Thermal Power Station (Gujarat). It was washed to remove excess fines and oven dried at 100^0C for 24 hours before its use in experiments. It is gray colored material having specific surface area 6177.15 cm^2/gm. Its chemical composition is approximately as SiO_2 - 51 to 55%, Al_2O_3 – 26 to 28%, Fe_2O_3 -3 to 6%, CaO -3 to 5 %, MgO – 3 to 5% and S as SO_3 trace. The known quantity (1 liter) of sample is treated with different amount of fly ash viz 2, 10, 20, 50, 100, 150, 200 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 BOD removal. The method for determination of BOD practicable is 5 Day Incubation Iodometric titration method contains DO (Dissolved Oxygen) measurement followed from 'Standard methods for the water and waste water' [20]. The results for each dose are presented in Table I, II and figure 1, 2.

RESULTS AND DISCUSSION

Table I shows the influence of dose variation of fly ash onto various physico-chemical characteristics of the combined waste water of Sugar Industry at room temperature. The pH of the sample increased with increase in dosage i.e from 7.05 to 7.97. Conductance and hardness decreased upto 50 gm/L and then remain constant for higher dosages. Conductance decreases from 3.9 m mho (initial) to 3.33 m mho and hardness decreases from 2610 mg/L (initial) to 2060 mg/L. The alkalinity decreased considerably from 2625 mg/L (initial) to 1700 mg/L with increasing amount of fly ash. Chloride content reduced slightly upto 187.441 mg/L from 104.936 mg/L (initial) by 10 gm/L of fly ash. The initial COD content of the waste water was 4979.52 mg/L is reduced to 3734.64 mg/L with 200gm/L of fly ash and remains the same at 400gm/L. the BOD content in the initial stage was 1410.5 mg/L is decreased to 1116 mg/L by 150gm/L of fly ash and remain constant for higher doses.

Table II represents the data for Freundlich and Langmuir adsorption isotherms along with percent removal of BOD exerting components. There is a considerable decrease in adsorption per unit weight of adsorbent with increase in adsorbent concentration. The removal of BOD contributing components is found to decrease from 46.5 mg/gm to 0.7362 mg/gm respectively with varying amounts of fly ash from 2 gm/L to 200gm/L

Figure- 1 represents the plot of log C_{eq} Vs log x/m for BOD on fly ash. 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 11.4454 for BOD while intercept K on Y-axis related to adsorption capacity is found to be 0.25

Figure- 2 represents the plot of Langmuir parameters viz, $1/C_{eq} \times 10^3$ and $1/q_e \times 10^3$. The nature of the curve for BOD onto fly ash from thermal power station is linear however the intercept on X-axis related to adsorption energy (L/mg) i.e. $b \times 10^3$ is 0.7510 L/mg for BOD exerting components. These values can be used to calculate the adsorption capacity θ_0 i.e 9.2248 (mg/gm).

Influence of different dose of fly ash on various physico-chemical characteristics can be explained as the pH increases with increasing amount of fly ash suggest the presence of basic components into fly ash which leads to higher the results. The conductance, hardness, chloride content and alkalinity removal can be explained by adsorption phenomena similar to that of organic constituents like COD and BOD.

Table II represents the data for Freundlich and Langmuir adsorption isotherms along with percent removal for COD onto fly ash. 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 fly ash confirm the applicability of Freundlich adsorption isotherm[8-11]. 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 BOD by fly ash. Langmuir isotherm is a plot of the amount of impurity adsorbed by fly ash 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 [8-11], 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)
θ_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 BOD contributing components onto fly ash. The straight line nature of the plot confirms the applicability of the Langmuir model and also the monolayer coverage. The Langmuir constant θ_0 in mg/gm related to adsorption capacity indicate availability of more surface active region onto adsorbent site and b x 10^3 L/mg related to adsorption energy in terms of x/m is a characteristic of the system.

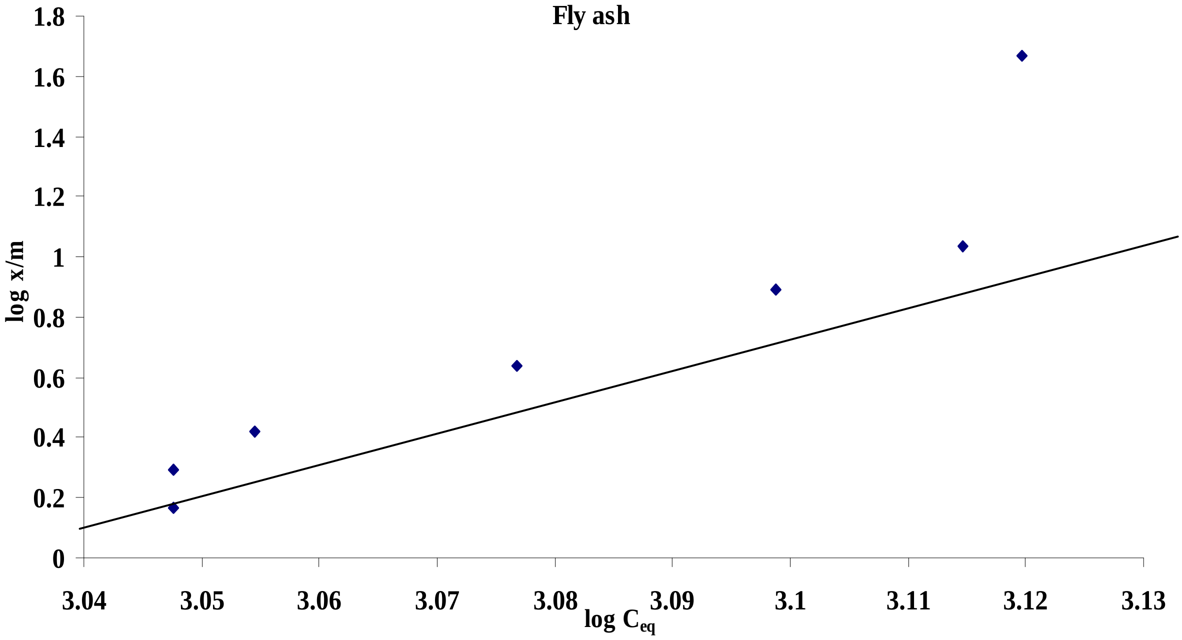
Table I The influence of dosage variation of Fly ash on various physico-chemical characteristic of Sugar Industry Waste Water

Adsorbent: *Fly ash* ***Room temperature:*** *25± 1 ^{0}C*

Specific Surface Area: *6177.15 Cm^2/ gm* ***Contact duration:*** *24 Hours*

Parameter	Untreated	2 gm/L	10 gm/L	20 gm/L	50 gm/L	100 gm/L	150 gm/L	200 gm/L
pH	7.05	7.55	7.6	7.68	7.71	7.84	7.05	6.97
Conductance (m mho)	3.92	3.75	3.7	3.61	3.2	3.33	3.53	3.26
COD (mg/L)	4979.52	4841.2	4633.72	4426.24	4149.6	3872.5	3803.8	3734.64
BOD (mg/L)	1410.5	1317.5	1302	1253.5	1193.5	1147.5	1196	1116
Alkalinity (mg/L)	2625	2250	2100	2000	1825	1800	1750	1700
Hardness (mg/L)	2610	2375	2300	2250	2060	2060	2060	2060
Chloride (mg/L)	204.93	199.93	187.44	187.44	187.44	187.44	187.44	187.44

Fig 1: Freundlich adsorption isotherm for BOD contributing component in Presence of Fly ash



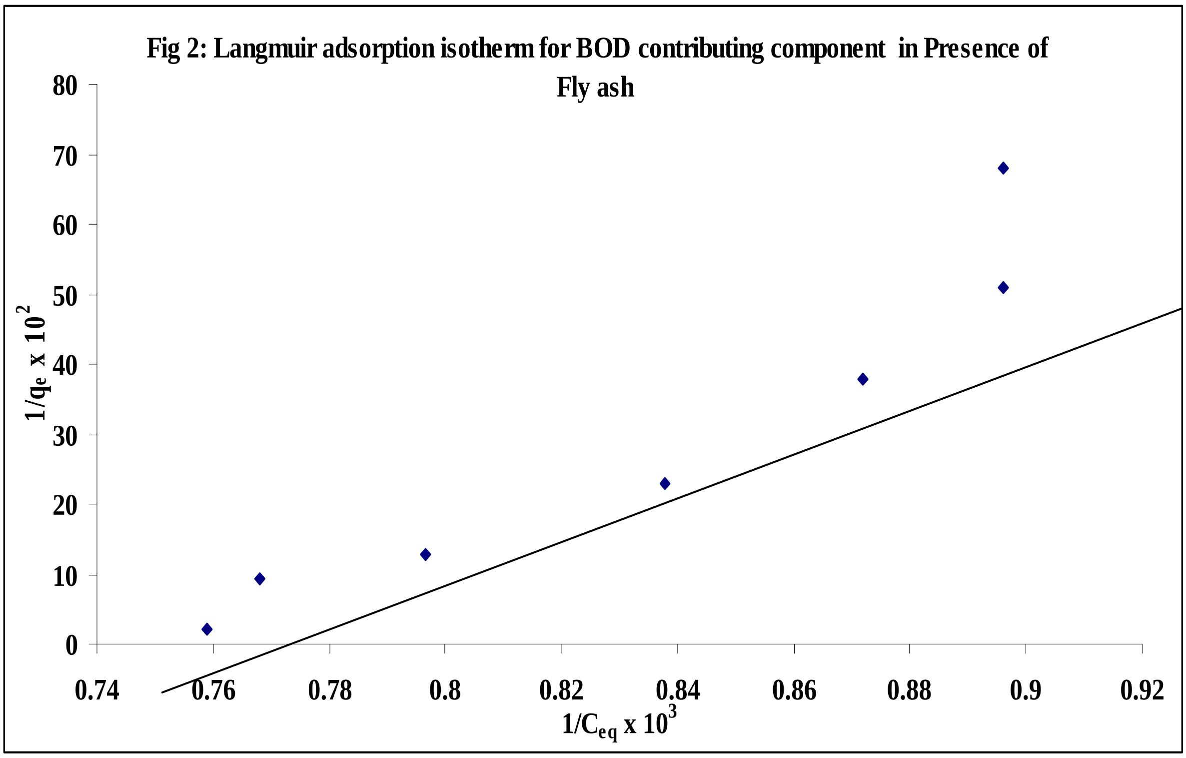


Table II Freundlich and Langmuir adsorption isotherms for BOD contributing component and percent removal of BOD in Presence of Fly ash

Adsorbent*: Fly ash* ***Room temperature:*** *25± 1 ^{0}C*

Specific Surface Area: *6177.15 Cm^2/ gm* ***Contact duration:*** *24 Hours*

No	Adsorbent Dosage m(gm/L)	Eq. Conc. C_{eq} (mg/L)	Removal $x=C_0-C_{eq}$ (mg/L)	q_e=x/m (mg/gm)	Removal %	logC_{eq}	logx/m	1/C_{eq}x10^3	1/q_ex10^2
1	0	1410.5	-	-	-	3.1494	-	0.7089	-
2	2	1317.5	93.0	46.5	6.59	3.1197	1.6674	0.7590	2.1505
3	10	1302.0	108.5	10.85	7.69	3.1146	1.0354	0.7680	9.2166
4	20	1255.5	155.0	7.75	10.99	3.0988	0.8893	0.7965	12.9032
5	50	1193.5	217.0	4.34	15.38	3.0768	0.6375	0.8379	23.0415
6	100	1147.0	263.5	2.6350	18.68	3.0545	0.4208	0.8718	37.95
7	150	1116.0	294.5	1.9633	20.88	3.0476	0.2929	0.8960	50.93
8	200	1116.0	294.5	1.4725	20.88	3.0476	0.1680	0.8960	67.91

CONCLUSION

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

i. The maximum COD removal is found at 200gm/L of fly ash concentration i.e. 25%
ii. Fly ash of the thermal power station removes 20.88% BOD contributing components of the waste water.
iii. The alkalinity, hardness and chloride content of the sample reduced with increasing amount of fly ash.
iv. At room temperature fly ash 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 0.25 while the slope 1/n is related to adsorption intensity is found to be 11.4454

b. The straight line of the Langmuir plot gives intercept on Y axis called b x 10^3 L/mg i.e. adsorption energy is 0.7510 and the calculated adsorption capacity θ_0 mg/gm is 9.2248

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