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Removal of Arsenic from wastewater by using coal fly ash as adsorbent

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Abstract
To examine the utilization of coal 'fly ash' as adsorbent, batch studies were conducted to assess the removal of arsenic (As) from wastewater. The parameters such as Effect of the Contact time, Concentration, Adsorbent's dosage, pH on Percentage removal was studied. The 'Langmuir' isotherm was well fitted to the experimental data and Adsorption kinetic studies concludes that 'pseudo second order' is best fitted for the data. The coal fly ash concentration required to accomplish the most extreme heavy metal removal was observed to be 6 g/L with the removal effectiveness of 96% of arsenic (As). The results of the study exhibited that the fly ash could be utilized as one of the successful low-cost adsorbent material for removal of Arsenic (As) from the wastewater.
Keywords: *Wastewater, Arsenic , Fly ash, Adsorption, Batch experiments.*
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I. INTRODUCTION

Developing nations like India, urban bodies have been helped ill-advised wastewater transfer system; because of the reason of substantial industrialization and ill-advised sewer water system. Though, a few chemicals based ventures released wastewater having dangerous components or substantial metals like Arsenic (As), Cadmium (Cd), Lead (Pb), Chromium (Cr), and so on which makes extreme harm to environment and human being [3]. Despite concentration of substantial metals in wastewater has turned into the significant issue to the living and non-living things in environment. In these respects, removal of heavy metals assumes the crucial part in definite transfer of wastewater into water bodies. Heavy metal particles are non-biodegradable; they can gather their entireties along the normal way of life. In this manner, it is basic important to expel or limit the heavy metal particles in wastewater efficiently. The treatment strategies for heavy metal removal from wastewater are chemical precipitation, chemical coagulation, ion exchange, electro chemical techniques, adsorption, zeolite, and membrane process. [4]. Present study is focussed on the adsorption to remove Arsenic (As) from the wastewater using coal fly ash as adsorbent.

II. MATERIALS & METHODS

2.1 Coal Fly ash

Coal fly ash remains (FA) is one which is produced in coal power stations (CPS) which is extremely stubborn to get wiped out from the biological system, causing natural risks, water and soil contamination and ruination of environmental cycles [9]. In India, out of 176.74 MT of FA produced by 151 TPSs, 107.77 MT is used for different purposes. From 1996-97 to 2015-16, there was an expansion of 6 overlap in the usage percentage of FA, i.e., from 10% to 60.97% ('Central Authority of Electricity', 2016). In this manner, keeping in mind the end goal to reduce hazards and hindrances caused by this harmful issue, a few kinds of research have been made to remove something great out of it. Around the world, just 25% of the aggregate FA produced is put into use. Reusing CFA rather than transfer is the best arrangement that deters natural worries, as well as makes new financial chances. Just less than 25% of the world's CFA is placed in different applications. For example: soil enhancement, Portland concrete and ceramic production, zeolites, filaments, fillers in polymers, adsorbents for air, and water and wastewater treatment. [10] Fig. 1 indicates distinctive usages of coal 'fly ash' in India.

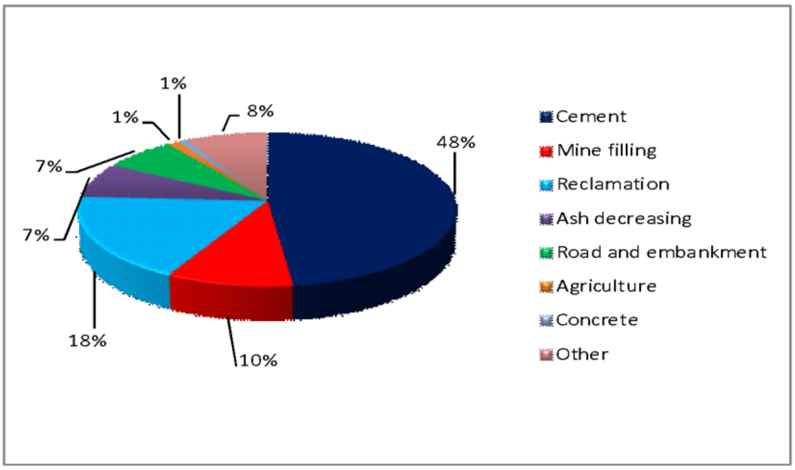

Fig.1: Coal fly ash utilization in India

In present work, the coal fly ash was collected from RTPP (Rayalaseema Thermal Power Plant) Kadapa district in Andhra Pradesh. Characterization of coal 'fly ash' was determined by using XRD (X-ray diffraction) as shown in Figure 2:

2.2 Preparation of Stock solution

Sodium arsenate sample was weighed by using electronic weighing balance and mixed with distilled water to make sample solutions with different concentrations of 2mg/L, 4mg/L, and 6mg/L respectively. Adsorbent (coal fly ash) dosage effect was studied by preparing 3 different solutions of 0.2g/100ml, 0.4g/100ml and 0.6g/100ml. The solution is prepared in 200 ml conical flasks and put in the Sonicator. The Calibration curve was prepared for different concentrations using UV-Spectrophotometry at wavelength of 228 nm.

2.3 Batch experiments

Batch experiments were conducted to remove arsenic (As) from wastewater by using fly ash. The effect of time (0-90min), concentration (2-6 mg/L), dosage (2-6 g/L), pH (4-8) was studied. After filtration the absorbance was determined by using UV-Spectrophotometry at wave length 228 nm.

III. RESULT AND DISCUSSION

3.1 Characterization of Adsorbent

XRD analysis of the Coal fly ash, Fig.2 shows that it contains SiO_2, Fe_2O_3, Al_2O_3, CaO and MgO. The XRD results of our sample compared with the standard JCPDS. It was established that the real portion of 2Theta values are coordinated with the JCPDS patterns of SiO_2 (JCPDS card No. 89-1668) and Fe_2O_3 (JCPDS card No. 89-0598). From the XRD estimations, it is concluded the fly ash material has the oxides such as SiO_2 (Si) and Fe_2O_3 (Fe).

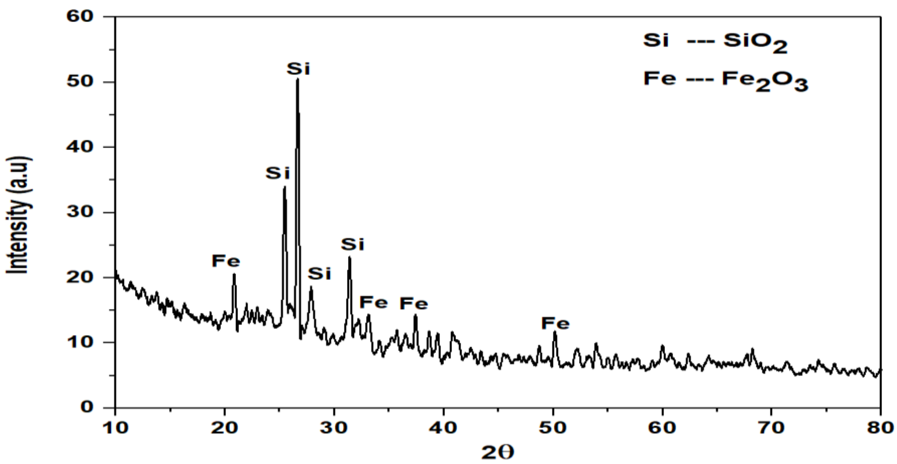

Fig 2: XRD Analysis for Coal Fly ash

3.2 Batch Adsorption Results

3.2.1 Effect of Contact time

The percentage removal of arsenic increases with the increase of contact time for an adsorbent dosage of 0.2g by changing the time. The adsorption of arsenic ion particle fluctuates from 60% to 94%. The highest percentage removal of arsenic is obtained after 90 (min). The percentage removal of Arsenic was constant after 90 (min). Percentage removal calculated from the equation (1).

Removal Percentage = $\frac{C_i - C_f}{C_i} X100$... (1)

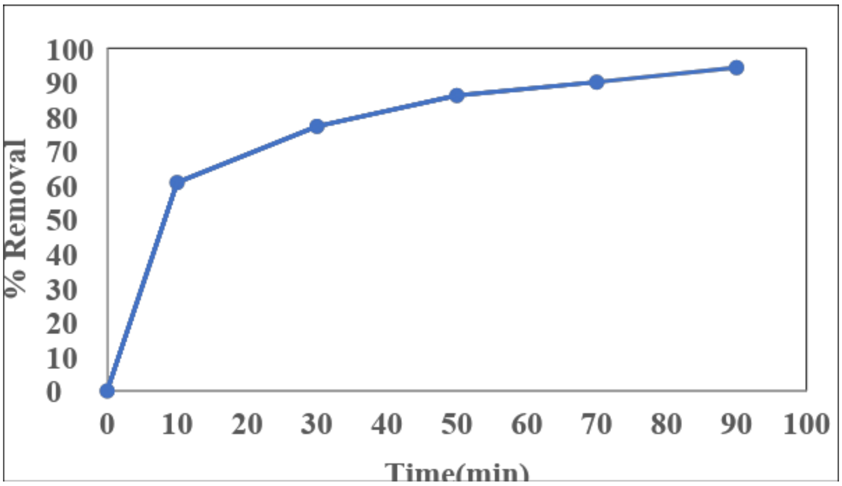

Fig 3: Effect of contact time on the percentage removal of Arsenic

3.2.2Effect of Dosage

The percentage removal of arsenic increases with the increase of dosage from 0.2g to 0.6g at constant concentration 2mg/L. For an adsorbent dosage of 0.6g the arsenic % removal was high because it causes the aggregation of adsorbent and the adsorption sites gets reduced due to adsorption density. The % removal of arsenic turns out to be relatively constant after 90min.

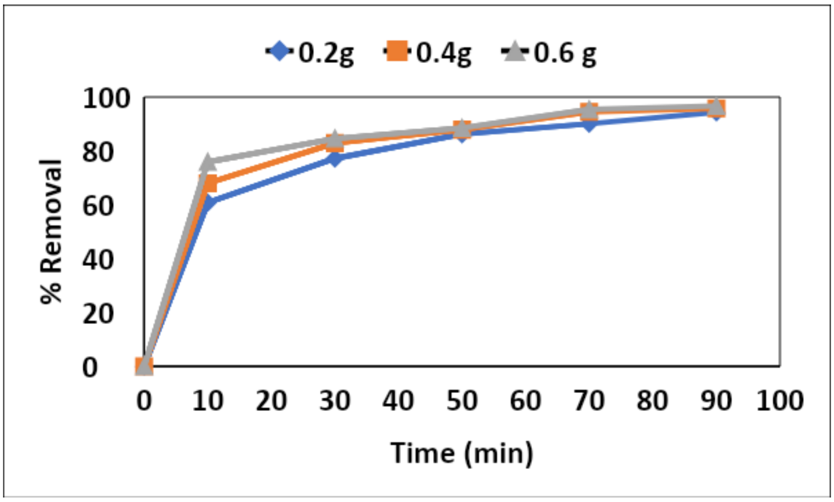

Fig 4: Effect of Adsorbent Dosage on the percentage removal of Arsenic

3.2.3Effect of Concentration

The percentage removal of arsenic decreases with the increase of concentration from 2 mg/L to 6 mg/L since, less amount of arsenic gets adsorbed on to the surface of the adsorbent. The % Removal was 94 % for concentration of 2 mg/L. It was 93%, 91% for concentration of 4 mg/L and 6 mg/L respectively.

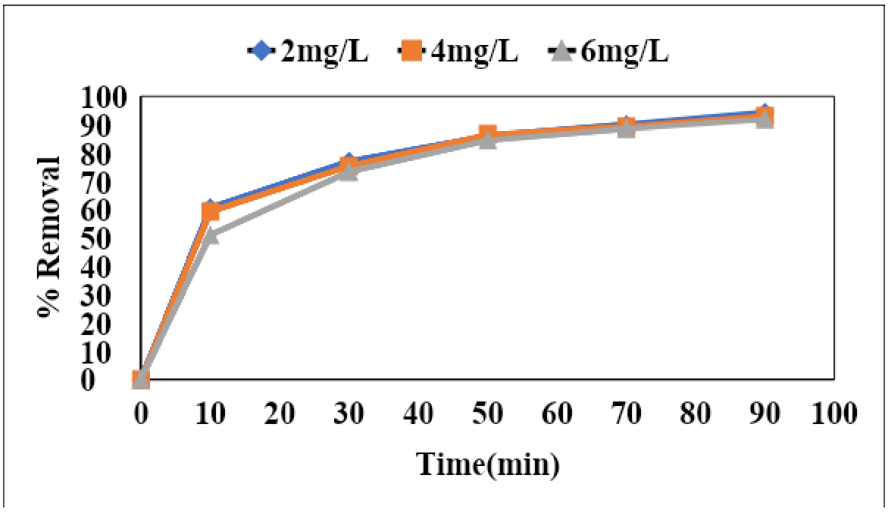

Fig 5: Effect of concentration on the percentage removal of Arsenic

3.2.4 Effect of pH

The Effect of pH on % removal of arsenic was studied at pH of 4, 6 & 8. The rate of removal of arsenic increases with increase of pH because of metal particle mobility and positive charged particles. The greatest % removal of arsenic was 96% acquired after 90(min) at pH 8.

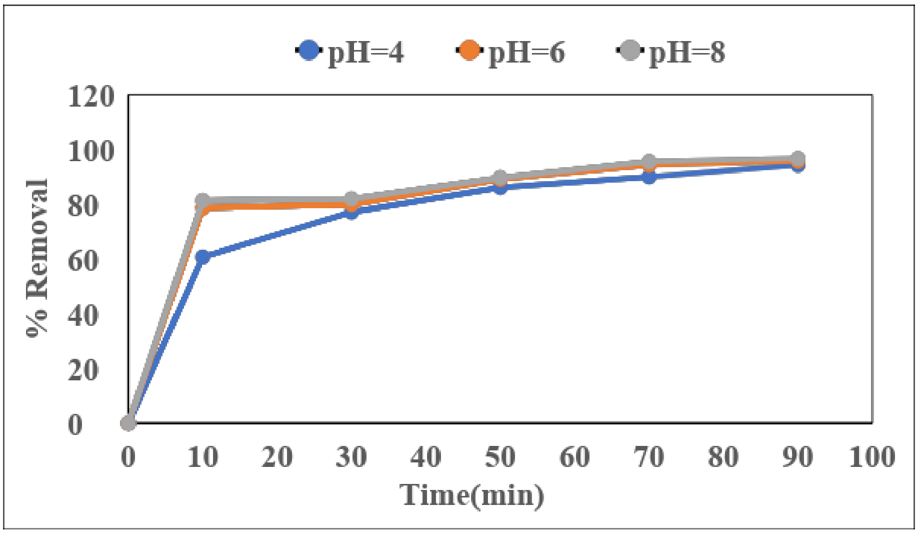

Fig 6: Effect of pH on the percentage removal of Arsenic

3.3 Adsorption Kinetic models

3.3.1 'Pseudo-First order Model': The equation of Pseudo-First order is given as; 'Intercept' gives qe and 'slope' gives k_1

$$\ln (qe- qt) = \ln qe- k_1 t \text{ …………………….. (2)}$$

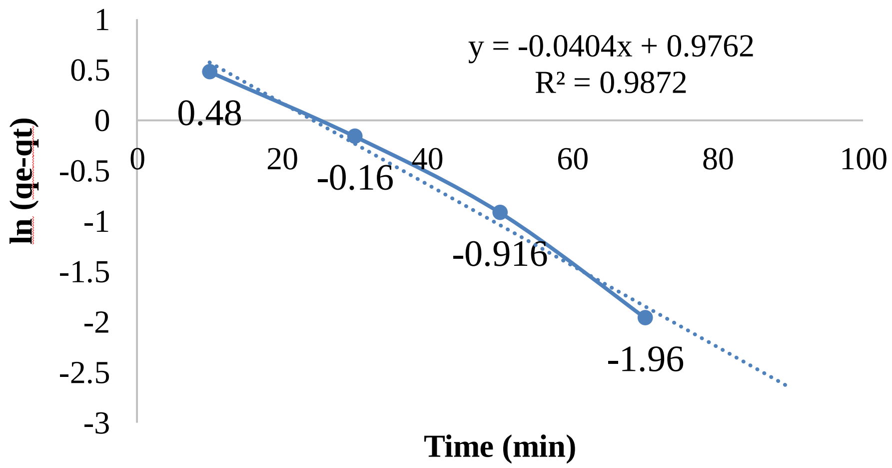

*Fig 7:*Pseudo-first order curve*

3.3.2 'Pseudo-second order model': The equation of Pseudo second order is given as;

$$\frac{t}{qt} = \frac{1}{k2\ qe2} + \frac{1}{qe} * t \quad \text{..............................} \ (3)$$

'Intercept' gives k_2 and 'slope' gives q_e

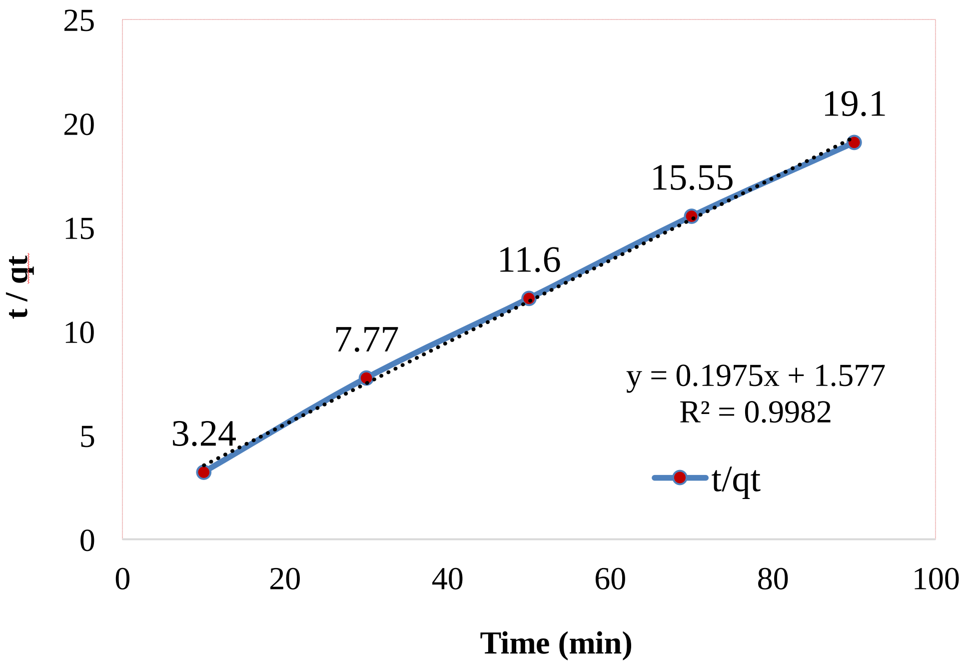

***Fig 8:** Pseudo-second order curve*

It was noticed that for second order equalization q_e value determined coincide well with the empirical value and R^2 value is more. For the first order q_e value computed contrasts much from the experimental value. The R^2 value is low when contrasted with the 'pseudo-second model'. Hence, it is evaluated that 'pseudo-second order' is best fitting 'kinetic model'.

3.4 Adsorption Isotherms

Langmuir isotherm and Freundlich isotherm plots were drawn as shown in Fig 8 and Fig 9

3.4.1 Langmuir isotherm model

$$\frac{c_f}{q_e} = c_f * \frac{a_l}{k_l} + \frac{1}{k_l} \quad \text{......................} \ (4)$$

A curve c_f/q_e Vs c_f are plotted, the 'intercept' gives k_l and 'slope' gives a_l/k_l.

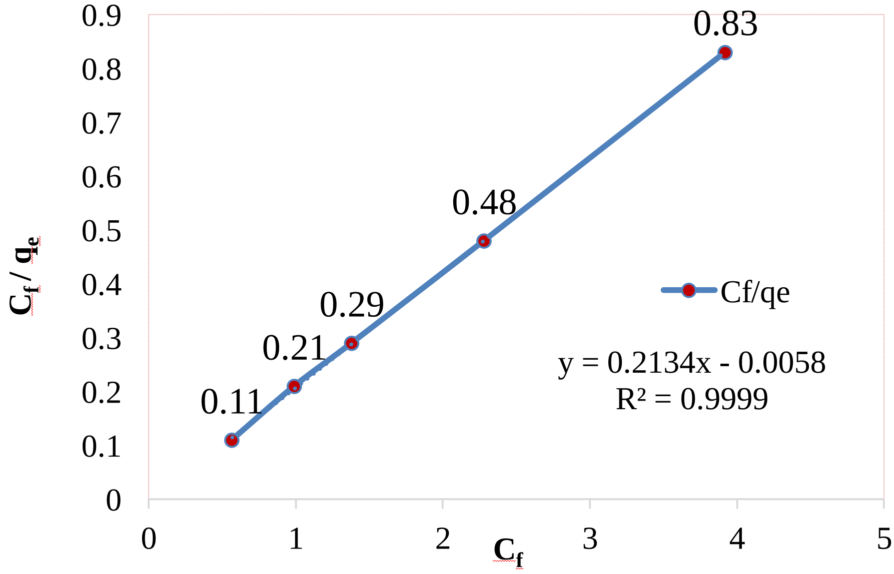

Fig 8: *Langmuir isotherm model*

The primitive favourable of the 'Langmuir isotherm' may be interface in terms of dimensionless consistent separation element (R_L) given via the accompanying condition:

$$R_L = \frac{1}{(1+a_L\, c_0)} \quad \text{............................ (5)}$$

R_L values inside the range $0< R_L<1$ demonstrate positive adsorption. Here, the value of R_L is 0.0027 for the initial arsenic concentration of 10 mg/L.

3.4.2 Freundlich isotherm model

$$lnq_t = \frac{1}{n} * lnc_f + lnk_f \quad \text{................................ (6)}$$

A trajectory ln (q_t) Vs ln (c_f) is conspire, the slope gives 'n' and intercept attempt K_f.

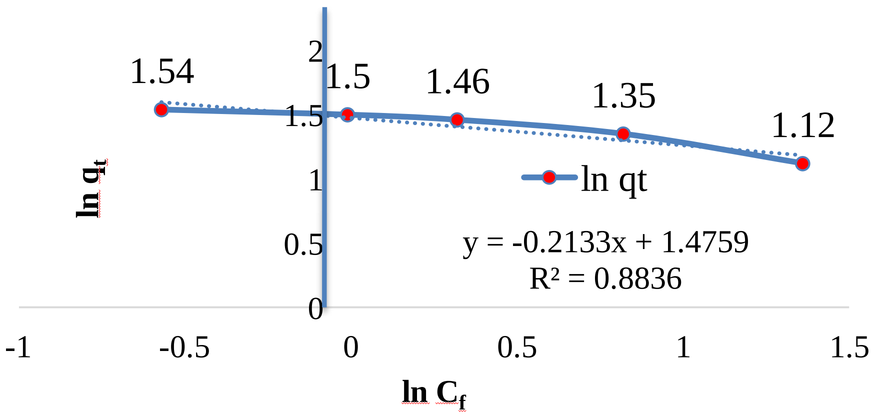

Fig 9: *Freundlich isotherm model*

Table 1: *Comparison of Langmuir &Freundlich Isotherm models*

	a_l	k_l	k_l/a_l	R_L	R^2
Langmuir Isotherm	36.79	172.41	4.686	0.0027	0.9999

	k_f	(1/n)	R^2		
Freundlich Isotherm	4.374	-0.2133	0.8836		

It is seen that both isotherm curves fit well with the adsorption system as their R^2 value is closer to 1.000. For fit of experimental isotherm data Langmuir equation fit well because its R^2 value is nearer to 1.000 than that of Freundlich model. Therefore, 'Langmuir model' demonstrate better based on 'regression coefficient'.

IV. CONCLUSIONS

- XRD analysis shows that coal 'Fly ash' contains of SiO_2, Al_2O_3, and Fe_2O_3.
- It is concluded that 96% Arsenic was removed at a pH of 8, fly ash dosage 6 mg/L and contact time of 90 min.
- In adsorption kinetics, R^2 value of Pseudo-second order model is high as compared to the 'pseudo-first order' model. Thus, Pseudo-second order is the best fitting kinetic model.
- In adsorption isotherms model, R^2 value of 'Langmuir isotherm' model is high when compared with 'Freundlich isotherm' model (i.e., R^2 value is closer to 1.000). Thus, it can be concluded that 'Langmuir isotherm' model is best fitting model because it describes monolayer adsorption.

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