ABSOLUTE ADSORPTION OF PARTICULATE MATTERS ON BIO-SORBENT (*With specific focus on Chicken Feather*)

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ABSTRACT

Adsorption of particulate matter on chicken feather was studied. Coal effluent was examined in the study. Batch adsorption was used to evaluate adsorption capacity of the feather-derived adsorbent. Highest removal of particles was recorded at maximum time of 60minutes. Also, increase in mass of adsorbent increases the rate of adsorption. Thus, the highest concentration of particles removed from the coal effluent was recorded at the maximum adsorbent mass (0.5g) under study. Adsorption was, also, undertaken at various constant temperatures (35, 40 and 45^oC), in which the rate of adsorption was found to be highest at the maximum temperature (45^oC), showing that adsorption capacity increases with rise in temperature. The correlation coefficient was determined using computer software (MS-Excel) and the experimental data were found to be well correlated (with high R^2 values). Adsorption isotherms (Freundlich and Langmuir models) employed in the indicated that the experimental data fitted well in the process.

Key words: Adsorption, Particulate Matter, Bio-sorbent}, Chicken Feather

INTRODUCTION

The discharge of untreated effluent wastes into the environment has continued to be a matter of concern globally. Pollutants, such as suspended/dissolved solids,

biodegradable organics, pathogens, nutrients, refractory organics and heavy metals are commonly found in these effluent wastes. However, most coal washery effluent reservoirs are exposed to the down-pours. To this effect, occasional heavy rainfall events have resulted to a periodically elevated concentration of particulate matters and turbidity in the wastewater effluents. Amy, et al (1992) reported that during these events, the concentration of solid particles in the raw effluent periodically exceed 3.3mg/l. In resent years, considerable attention has been focused on the use of bio-sorbents for wastewater treatment via adsorption. Generally, a sorbent can be assumed to be of low cost if it is readily available, a by-product of waste material from an industry, and/or requires little or no processing (Srivastava et al, 2001). Bio-sorption is a term that describes the removal of pollutants by passive binding to non-living micro-organisms (such as bacteria, fungi and algae) and other biomass (rice hull, fruit peel, leave/bark of a tree, peat, bone, feather, etc.) from an aqueous solution (Kushwaha et al, 2003). The mechanism of adsorption by bio-sorbents was found to be ionic exchange. Bio-sorbents contain various types of cationic sites, which enable them balance the anions of any aqueous solution. However, adsorption of particulate matters has been used for predicting how easily a re-usable wastewater can be made using a given effluent sample (Metcalf and Eddy, 2003).

In this study, the behaviour of chicken feather in coal effluent sample was examined. The effect of temperature, duration of contact and mass of adsorbent on the rate of adsorption were studied. Adsorption isotherms (Freundlich and Langmuir) were used to access the fitness of batch adsorption data.

THEORY

(A) *Freundlich Isotherm*

The Carbon Adsorption Capacity is given by:

$$q_t = (x/m)C_o \quad (1)$$

The Freundlich isotherm is defined as follows:

$$x/m = K_f C_t^{1/2} \quad (2)$$

Where x/m = mass of adsorbate adsorbed per unit mass of adsorbent (mg/g)

K_f = Freundlich capacity factor (l effluent/mg adsorbate)$^{1/n}$

C_t = concentration of adsorbate in solution after Adsorption (mg/l)

1/n = Freundlich intensity parameter.

Linearizing equation (2), we have:

$$\text{Log}\,(x/m) = \log K_f + 1/n \log (C_t) \quad (3)$$

The constants in the Freundlich isotherm are determined by plotting log (x/m) versus log (C_t), where log (K_f) and 1/n are the intercept and slope respectively.

(B) *Langmuir Isotherm*

The Langmuir isotherm is defined by the following expression:

$$\frac{x}{m} = \frac{abC_t}{1 + bC_t} \quad (4)$$

Where,

x/m = mass of adsorbate adsorbed per unit mass of adsorbent (mg/g)

a, b = empirical constants

C_t = concentration of adsorbate in solution after adsorption (mg/l).

Equation (4) can be rearranged as:

$$\frac{C_t}{x/m} = \frac{1}{ab} + \frac{1}{a} C_t \quad (5)$$

MATERIALS AND METHOD

The Effluent Sample Collection

The wastewater sample (*coal effluent*) was collected from the effluent holding pond of the Coal Mining Industry, Akwukwe-Enugu, located at the South-Eastern part of Nigeria. The soil in the region is rocky with high coal deposit. Concentration of particulate matters in the coal washery effluent is always high as a result of its exposition to down pours of rain.

The Sorbent

Chicken feather was used in the study as adsorbent. The feathers were collected from the chicken-slaughter points at Obinze market in Imo State of Nigeria, sliced and divided into two equal quantities (each containing 54g-wt of the sample). The samples were impregnated in

60% strength of orthophospheric acid and ammonium chloride salt, respectively, for 24-hours, in order to activate the feather samples. At the elapse of the time, the feather samples were removed and washed severally with distilled water to obtain samples of neutral or nearly neutral pH (using a Delta-320 pH meter). The samples were then inoculated in clean trays and dried by means of oven dryer. The samples were further inoculated in clay pots and subjected to carbonization process at a charring temperature of 300°C, using a furnace equipment of model- ***2KX0-60***. A ceramic mortar set was used to grind the adsorbent samples, and a sieve size of ***600µm*** was used to obtain the sample size used in the study.

Batch Adsorption Experiments

Batch adsorption experiment was carried out at room temperature (25-30°C). In each experiment, 20ml of the coal effluent of known initial concentration (0.33mg/l) was treated with a specific amount (by weight) of the activated feather-derived adsorbents (***0.1, 0.2, 0.3, 0.4 and 0.5g***), at various contact time (***5, 10, 15, 20, 25, 30, 35, 40 and 60mins***). The effluent sample was, also, treated at various constant temperatures (35°C, 40°C and 45°C) in order to observe the effect of temperature on the adsorption process. This was done using constant temperature regulation equipment (CTRE).

RESULTS AND DISCUSION

The adsorbent samples employed in this study evidently showed different adsorption strengths as may be seen in the concentration – time profiles (Fig 1 & 2). The results showed that as time proceeded in line with increase in mass of adsorbent, more particulate matters are being removed from the coal effluent. The results, also, indicated lower rate of adsorption by Salt- treated adsorbent when compared with the Acid-treated ones. This observation may be attributed to the fact that Acid-Based Feather **(ABF)** possessed larger pore size than the Salt-Based Feather **(SBF)**, which increases there point charge interaction with the solid particles in the effluent waste water sample (Snoeyink and Summers, 1999).

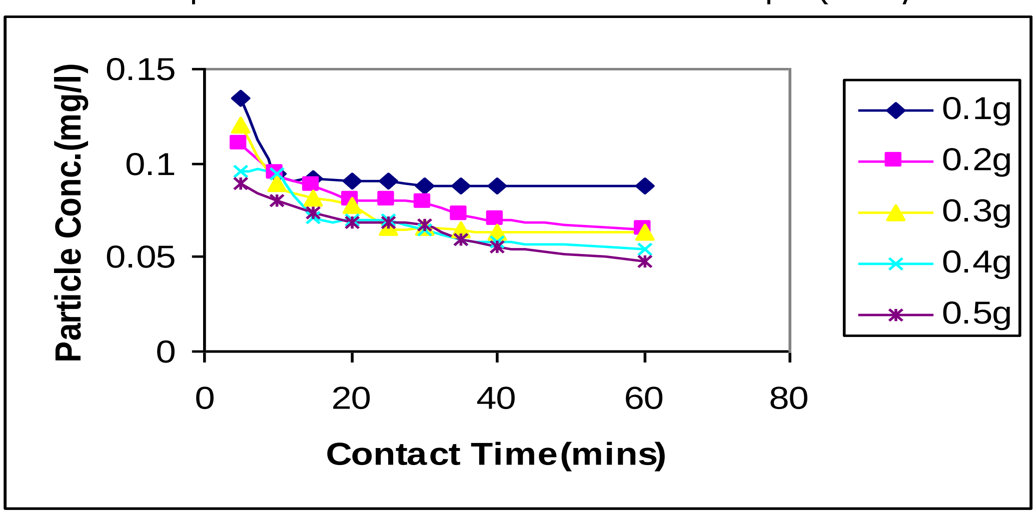

Fig 1: Plot of Concentration of Particles versus Contact Time at Varying Masses of Acid-Based Feather (ABF) (C_o = 0.33mg/l)

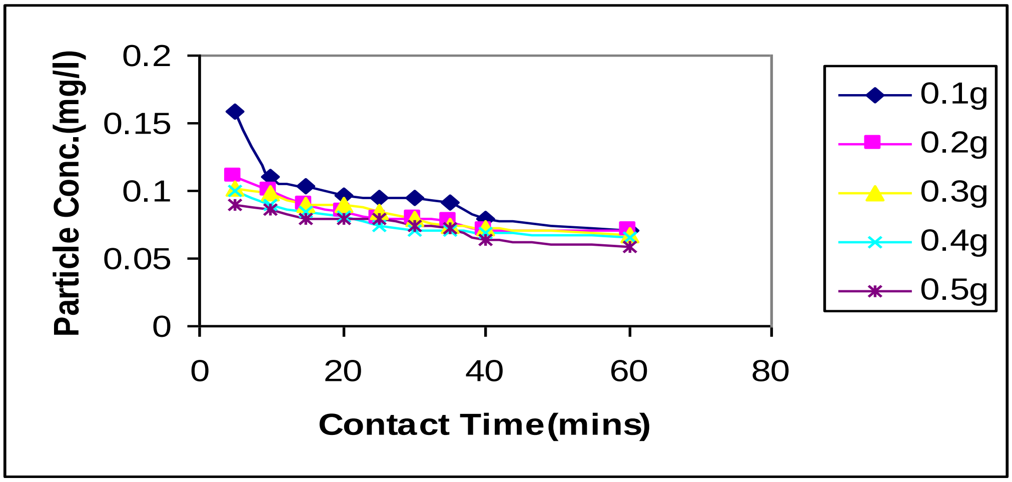

Fig 2: **Plot of Concentration of Particles versus Contact Time at Varying Masses of Salt-Based Feather (SBF) (C_o = 0.33mg/l)**

Batch Adsorption was carried out at three different constant temperatures (35, 40 and 45°C), keeping the feed concentration and adsorbent mass constant. With increased temperature (from 35 → 40 → 45°C), rate of adsorption of particles increased (Fig. 3 & 4). This indicates that adsorption is an endothermic process. As the temperature increases, the number of active sites available for adsorption must have increased, resulting in the enhancement of percentage adsorption of the adsorbate on the feather-derived adsorbents. Maximum adsorption was recorded at 45°C, while the minimum adsorption was recorded at 35°C. Meanwhile, the possibility of decreasing the thickness of the boundary layer surrounding the adsorbent (with rise in temperature) cannot be ruled out entirely, since this tends to reduce the mass transfer resistance of the adsorbate in the boundary layer (Coskum et al, 2006). However, as diffusion is an endothermic process, increase in the up-take of particles may be due to an enhanced rate of inter-particle diffusion of the adsorbate; and increase in pore diffusivity of the adsorbate (with rise in temperature) leads to increase in the percentage removal of the particles (Maiti et al, 2003).

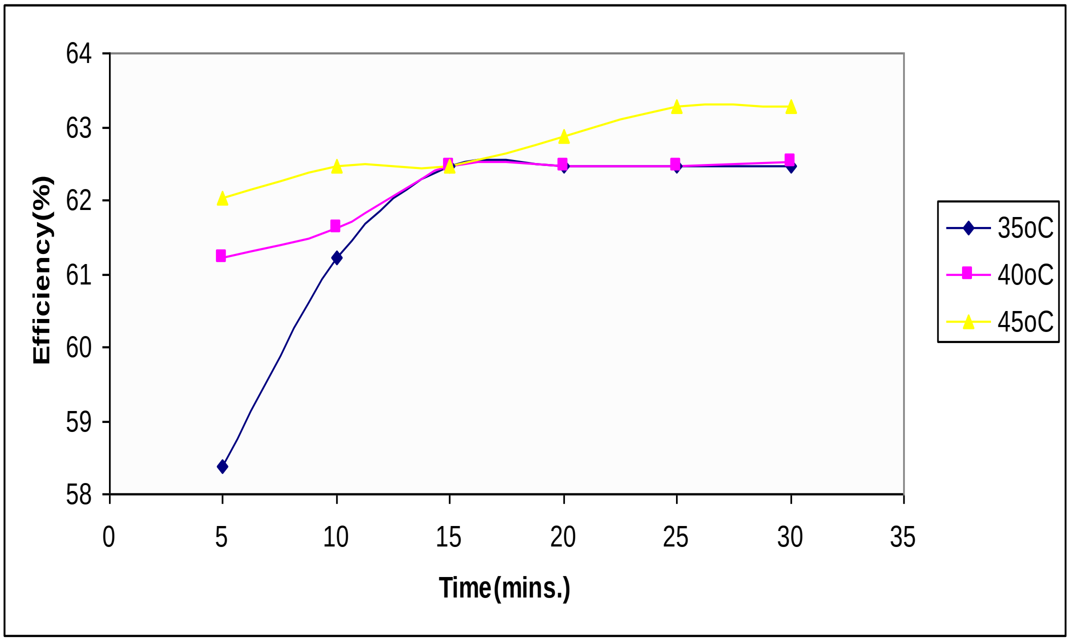

Fig 3: Behaviour of Acid-Based Feather (ABF) at Various Constant Temps.

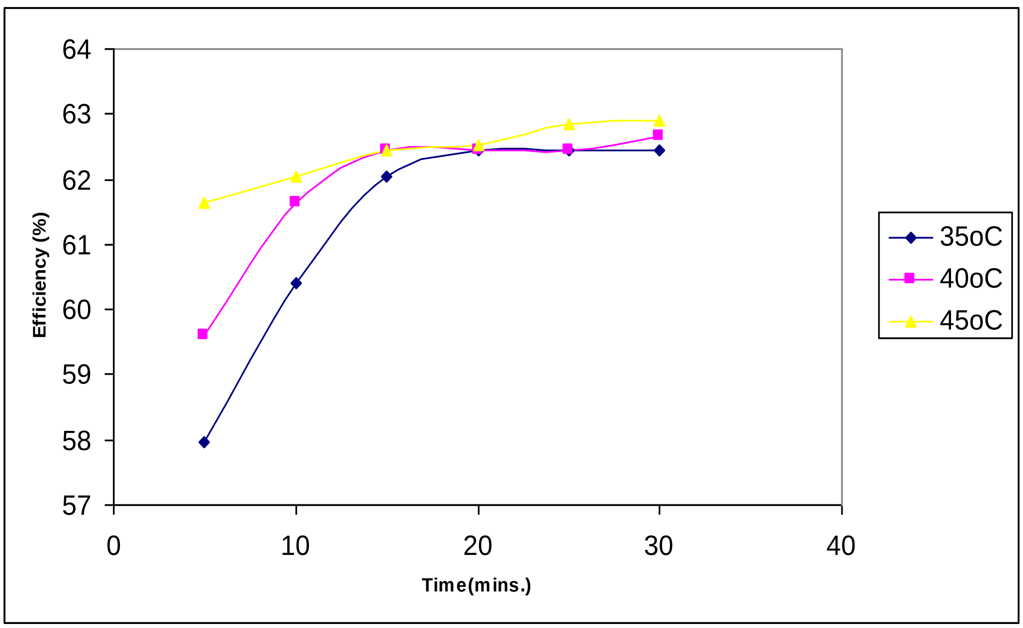

Fig 4: Behaviour of Salt-Based Feather (SBF) at Various Constant Temps.

The coefficients of Freundlich and Langmuir isotherm models (Table 1) provided information on the maximum amount of activated carbon adsorbent (***ABF*** and/or ***SBF***) required to adsorb a specific adsorbate concentration. The values of the favourability factors: **1/n** and $\mathbf{R_L}$ (<1) for Freundlich and Langmuir models respectively indicate favourable adsorption process (Table 1); smaller value of **1/n** and $\mathbf{R_L}$ shows better adsorption mechanism and the formation of relatively strong bond between the particles and the adsorbent (Kushwaha et al, 2003). The correlation coefficients (R^2) for both isotherms were calculated to know how well the experimental data fit the adsorption process.

Table 1: Isotherm Parameters for Freundlich and Langmuir Models

Freundlich Constants				**Langmuir Constants**			
Adsorbents	**k_f(l/mg)**	**$1/n$**	**R^2**	**a**	**b**	**R_L**	**R^2**
ABF	**92.85**	**0.2364**	**0.979**	**0.0228**	**-2.1215**	**0.004**	**0.946**
SBF	**67.34**	**0.6250**	**0.982**	**0.0229**	**-2.1188**	**0.019**	**0.971**

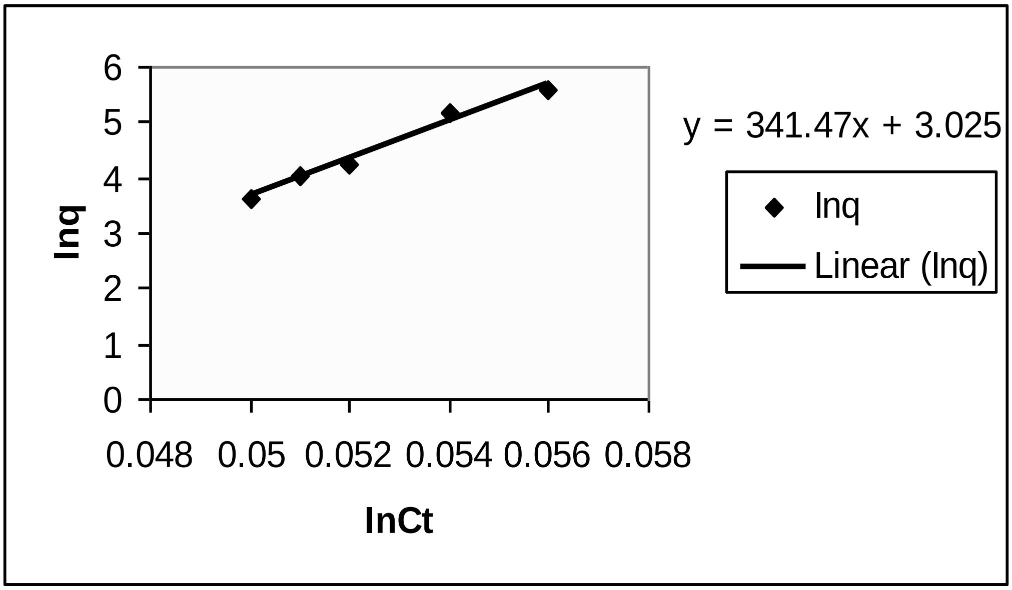

Fig 5: Freundlich Plot for ABF

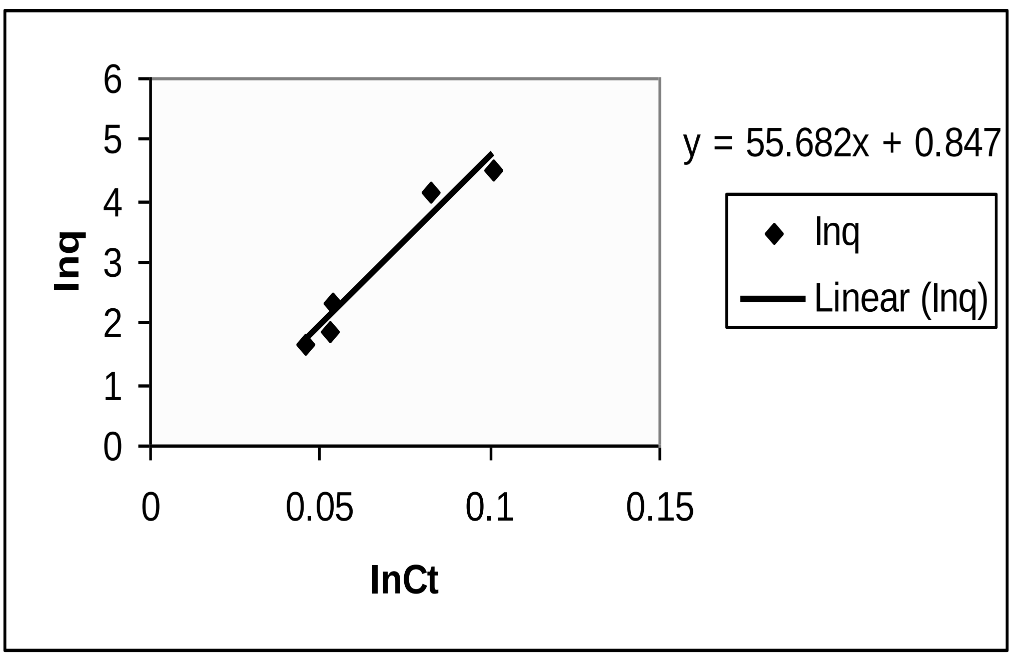

Fig 6: Freundlich Plot for SBF

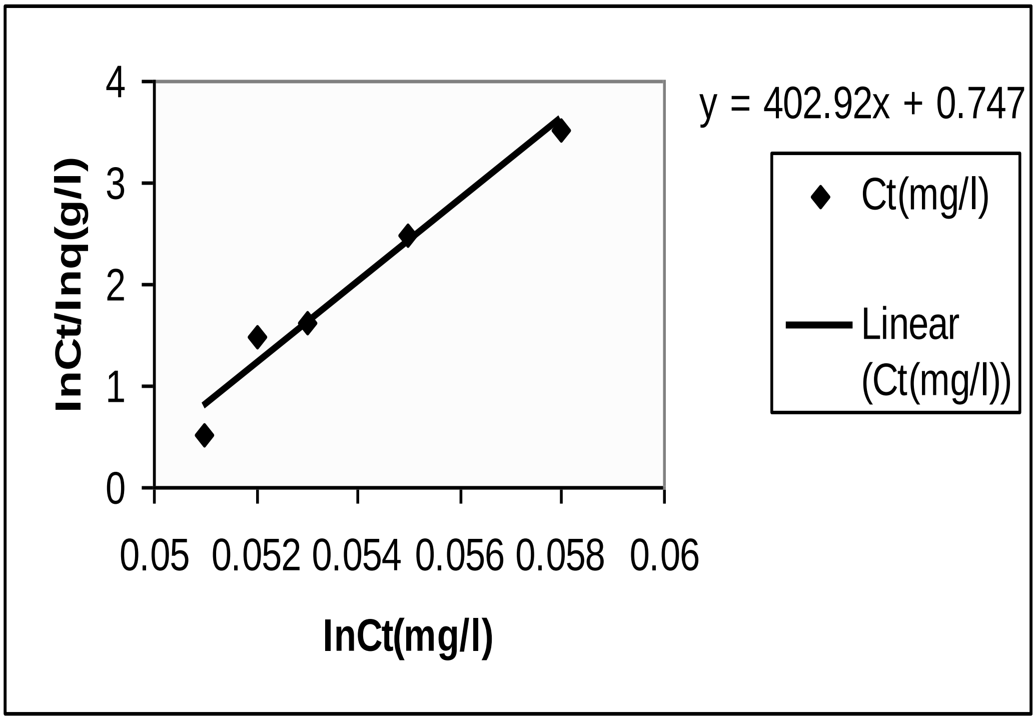

Fig 7: Langmuir Plot for ABF

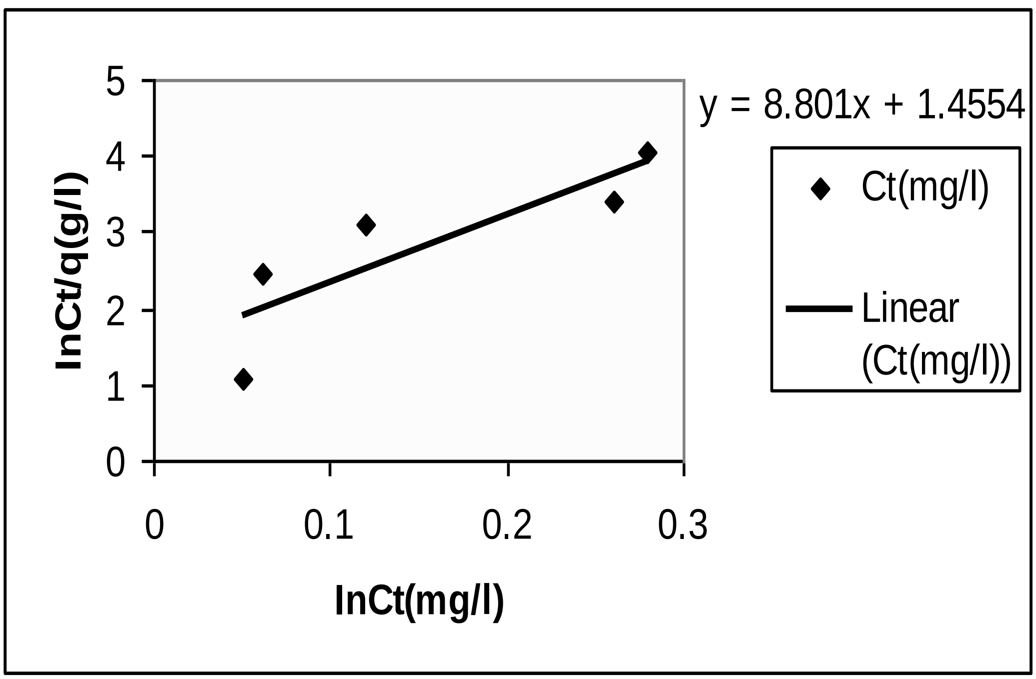

Fig 8: Langmuir Plot for SBF

CONCLUSION

The adsorbent samples showed high level of reliability. Maximum removal was recorded at the highest contact duration (60mins) with the maximum adsorbent mass of 0.5g. Increase in temperature increases the rate of adsorption. Though both Freundlich and Langmuir models fit the experimental data, the correlation coefficient (R^2) values suggest that Freundlich model fitted the data more than the Langmuir model.

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