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To Study Application of Different Isotherm Models on Bismuth (III) Ions Adsorption onto Impregnated Granular Activated Charcoal

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ABSTRACT

Adsorption has been proved to be an excellent way to treat industrial waste effluents, offering significant advantages like the low-cost, availability, profitability, easy of operation and efficiency. In this paper four parameter isotherm model namely Langmuir, three parameters namely Freundlich and Temkin were applied to describe the isotherm and to calculate their constant. The best estimation of the parameters of these models by non-linear regression analysis was obtained. A comparison between four and three parameters isotherm was reported. The characteristic parameter of each isotherm and related coefficient of determination (R^2) have been determined. All the coefficient of determination (R^2) of the non-linear method are close to unity. The effect of various parameters influencing the Bi(III) adsorptions such as effect of pH, Contact time, temperature, adsorbent dose have been studied. Maximum adsorption found to be 81.13 at pH 1. The results indicate that surface modification with N-Lauroylsarcosine sodium salt (NLSSS) could be used to significantly enhance the capacity of granulated activated charcoal to adsorb Bi(III) metal ion.

Keywords: Granular Activated Carbon, N-Lauroylsarcosine sodium salt, Adsorption, Impregnation, Isotherm, Bismuth.

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INTRODUCTION

Now day's heavy metals are among the most important pollutants in source and treated water, and are becoming a severe public health problem. Industrial and municipal waste waters frequently contain metal ions. Industrial waste constitutes the major source of various kinds of metal pollution in natural water¹⁻⁴. Heavy metal ions are reported as priority pollutants, due to their mobility in natural water ecosystems and due to their toxicity⁵⁻⁶. The heavy metal ions are stable and persistent environmental contaminants since they cannot be degraded and destroyed. These metal ions can be harmful to aquatic life and water contaminated by toxic metal ions remains a serious public health problem for human health. Heavy metals removal from aqueous solutions has been traditionally carried out by chemical precipitation⁷. Different methods, such as precipitation⁸, solvent extraction⁹ chemical and Electrochemical techniques¹⁰, ion-exchange methods¹¹ ultra filtration¹² and reverse osmosis¹³⁻¹⁴, flotation¹⁵ and coagulation¹⁶ have been developed for the removal of toxic metal ions from industrial effluents and wastewaters. However, most of these processes are unacceptable, owing to the disposal of sludge, their high cost, low efficiency and inapplicability to a wide range of pollutants¹⁷. Adsorption is a well-known separation method and recognized as one of efficient and economic methods for water decontamination applications. In addition, owing to the reversible nature of most adsorption processes, the adsorbents can be regenerated by suitable desorption processes for multiple uses¹⁸, and many desorption processes are of low maintenance cost, high efficiency, and ease of operation¹⁹. However, the major problem in this field is to select novel types of adsorbents. A number of adsorbents such as activated carbon²⁰, zeolites²¹⁻²², clays²³⁻²⁴ and agricultural residues²⁵⁻²⁷ have been used for the removal of heavy metal ions. However, the major disadvantages of these adsorbents are their low adsorption capacities, their relatively weak interactions with metallic ions and difficulties of separation and regeneration of some of them from water. To overcome these limitations in the present study granulated activated charcoal impregnated with N-Lauroylsarcosine sodium salt to improve the adsorption efficiency of granulated activated charcoal and study the applications of different isotherm models.

MATERIALS AND METHODS

In these experiments, we used a granular activated carbon. This GAC having iodine absorption value 750-800 mg/gm purchased from Loba chemie, N-Lauroylsarcosine sodium salt purchased from Acros organics, Bismuth solution (0.005M) were prepared by dissolving analytical grade BiCl₃ (Qualigens) volumetrically in deionised water. N-Lauroylsarcosine sodium salts (0.01M) were prepared volumetrically in deionised water. Surface modification and other study is carried

out according to Gunjate Jitendra K²⁸.

Surface Modification of Activated Carbon

The activated carbon was washed several times with deionised water, and then dried for several days in an oven at 60⁰C. The resulting unmodified dried granular activated carbon (virgin GAC) was modified by impregnating it with the N-Lauroylsarcosine sodium salt as follows. By taking 200ml solution of N-Lauroylsarcosine sodium salt (0.01M) and 0.5 gram GAC in reagent bottle and shake for 3 hours at 1000 rpm at 300 K. Then washed and re-dried as described above. The resultant loaded granulated activated charcoal with N-Lauroylsarcosine sodium salt designated as (GAC-NLSSS).

Batch Experiment for Bi (III) Adsorption

The capacities of virgin GAC and GAC-NLSSS to adsorb Bi (III) were examined by measuring the initial and final concentrations of Bi (III) in a batch system. Experiments were conducted in 250mL flasks with a working volume of 200 ml. To examine the effect of pH on Bi (III) removal by the granulated activated carbons, solutions of GAC-NLSSS were obtained by adding 0.5 g samples to 200 mL of 0.005M Bi (III) solution, then adjusting the pH to 0.3 to 2.2 by adding 1N NaOH or H₂SO₄ as required. The solutions were shaken at 1000 rpm at 300 K for 3 Hours.

Effect of pH on Bi (III) Adsorption

pH has an important effect on the interactions between adsorbent and adsorbate, batch adsorption experiments with virgin GAC and GAC-NLSSS were conducted at various pH from 0.3 to 2.2. The virgin GAC removed Bi (III) poorly at all pHs even at pH 2.2. Thus, the low capacity of virgin GAC to adsorb Bi (III) is a result of its low acidity. GAC-NLSSS removed 81.13% Bi (III) even at pH 1.0 shown in Figure 7. Impregnating activated carbon with NLSSS ligands increased the number of active sites capable of binding the Bi (III) ions.

Effect of Contact Time

The effect of Contact time on the amount of Bi (III) ions adsorbed was investigated by using various initial concentration of Bi (III) ions with 0.5 gram GAC-NLSSS and GAC. The effect of Contact time and metal ions concentrations on the percent removal of Bi (III) by GAC-NLSSS and GAC is shown in Figure 5. The result indicates that removal of Bi (III) ions increases with increase in Contact time and equilibrium was attained in about 400 min. The extent of removal of Bi (III) by GAC-NLSSS and GAC was found to increase, reach a maximum value with increase in contact time.

Effect of Dose

To understand the effect of dose, 200 ml of Bi (III) solution of 0.005 M were shaken at 1000 rpm

at 300 K., by varying the dose of adsorbent from 0.2 to 1.6 gram in eight different bottles. The result indicates that as the amount of adsorbent dose increases the adsorption efficiency of GAC and GAC-NLSSS also increases. GAC-NLSSS shows higher adsorption capacity than virgin GAC, Shown in Figure 6.

Adsorption Isotherms

Equilibrium isotherms were studied for Langmuir, Freundlich and Temkin isotherms. The results are shown in Figures 1-A, 1-B, 2-A, 2-B, 3-A, 3-B which, illustrate the plot of Langmuir, Freundlich and Temkin isotherms of Bi (III) on GAC and GAC-NLSSS.

The linearised form of the Langmuir isotherms is

$$\frac{1}{q_e} = \frac{1}{q^0 b} \times \frac{1}{C_e} + \frac{1}{Q^0}$$

Where ‘ Q^0 ’ and ‘ b ’ are Langmuir constants. The plot of $1/C_e$ Vs $1/q_e$ was found to be linear, indicating the applicability of Langmuir model. The parameters ‘ Q^0 ’ and ‘ b ’ have been calculated and presented in Table No.-II. The Langmuir constant ‘ Q^0 ’ is a measure of adsorption capacity and ‘ b ’ is the measure of energy of adsorption. In order to observe whether the adsorption is favourable or not, a dimensionless parameter ‘ R ’ obtained from Langmuir isotherm

$$R = (1 + b \times C_m)^{-1}$$

Freundlich isotherm studying by plotting graph $\log C_e$ Vs $\log q_e$ and the equation is conveniently used in the linear form by taking the logarithm of both sides; the parameters are represented in Table 2.

$$\log q_e = \log K_f + 1/n \log C_e$$

Where “ K_f ” is the adsorption capacity and “ $1/n$ ” or “ B ” is the intensity of adsorption.

Temkin model assumes effect of some indirect interactions amongst adsorbate particles and suggests linear decrease in the heat of adsorption of all the molecules in the layer, due to these interactions. Temkin linear isotherm form is expressed as follows

$$q_e = a_t + 2.303 b_t \log C_e$$

Where a_t and b_t are Temkin constant. Values of a_t , b_t are calculated respectively from the intercept and the slope of the plot of q_e vs. $\log C_e$

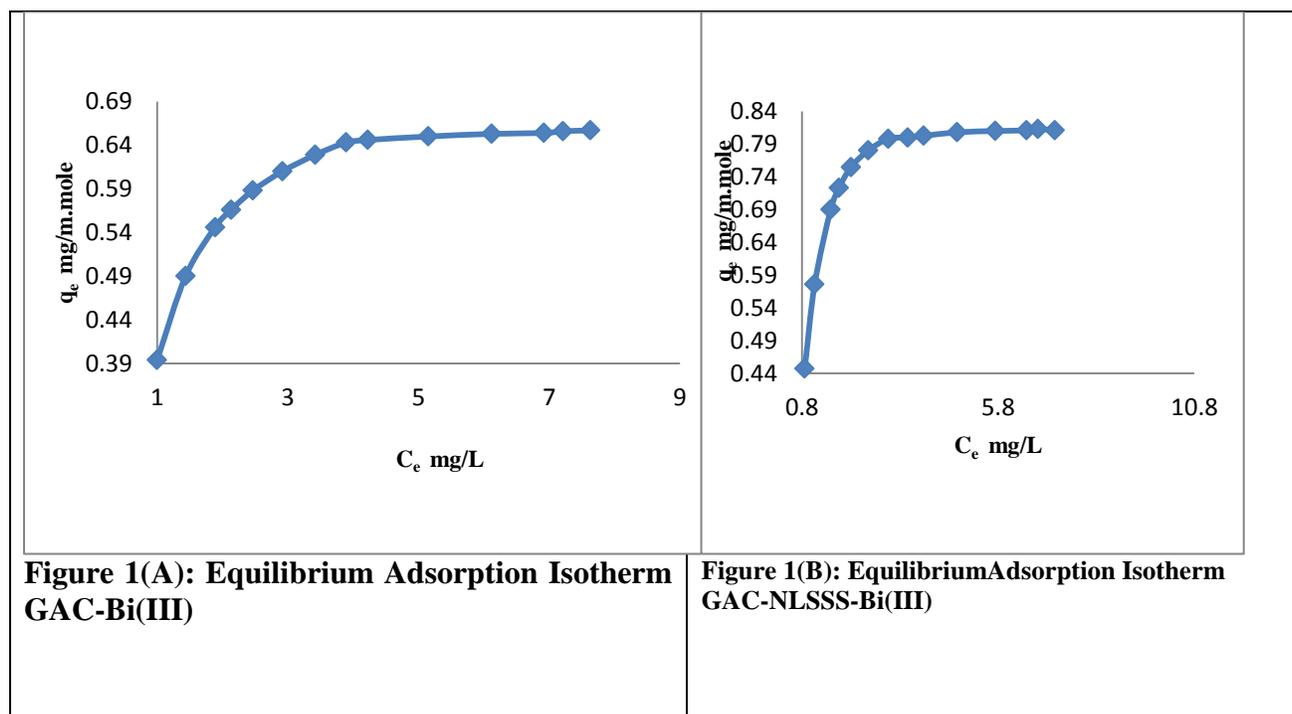
The experimental data yielded excellent fits within the following isotherm: Langmuir > Temkin > Freundlich isotherms based on its R^2 value.

RESULTS AND DISCUSSIONS

The results obtained in this study clearly demonstrated the potential use of GAC-NLSSS for the

removal of Bi^{3+} ions from aqueous solutions. The following Results can be drawn based on the investigation

- The percentage efficiency of removal of Bi^{3+} ions from aqueous solutions increases with increase in amount of adsorbent up to 1.6 g per 200 ml sample, after which percentage removal almost remains constant.
- Virgin GAC uptake low percent of Bismuth (III) even at pH 2. While GAC-NLSSS adsorbs capacity is 81.13% Bismuth (III) ion even at pH 1.
- The effect of temperature for retrieval of Bi^{3+} studied at different temperature at 40° , 50° , 60° , 70° , 80° , 90° . The maximum retrieval efficiency was found at 80° after that it was constant.
- The rate of adsorption is rapid upto 240 min and then rate of adsorption increase gradually and it becomes constant after 4 hours.
- From the result it conclude that impregnated granulated activated charcoal with N-lauroylsarcosine sodium salt act as a potential adsorbent for the removal of Bismuth (III).
- The experimental data yielded excellent fits within the following isotherm order: Langmuir > Temkin > Freundlich isotherms based on its R^2 value.



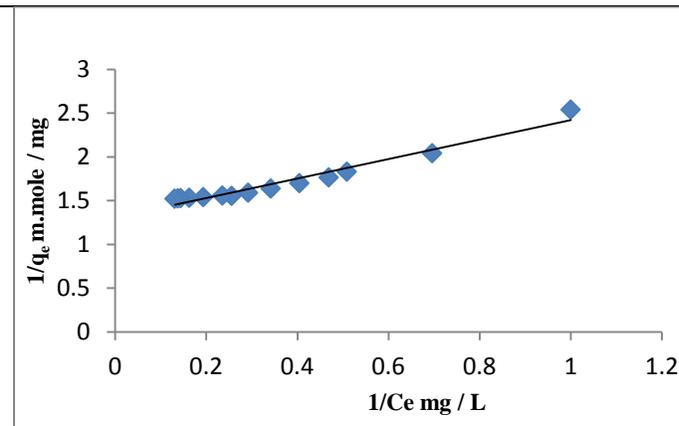


Figure 2(A) Langmuir Isotherm GAC-Bi (III)

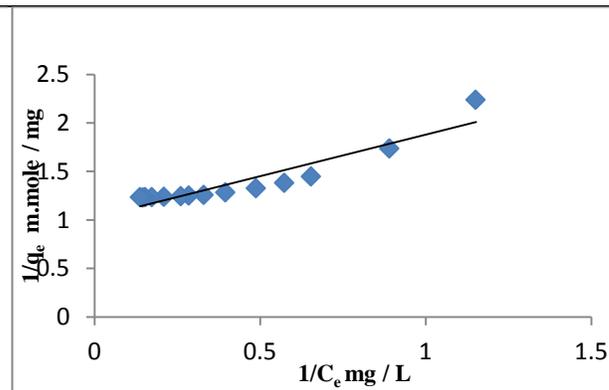


Figure 2(B): Langmuir Isotherm GAC-NLSSS-Bi (III)

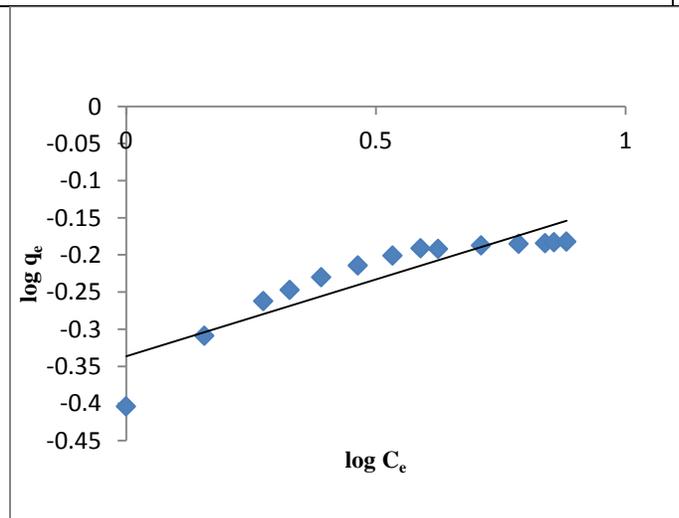


Figure 3(A): Freundlich Isotherm GAC-Bi(III)

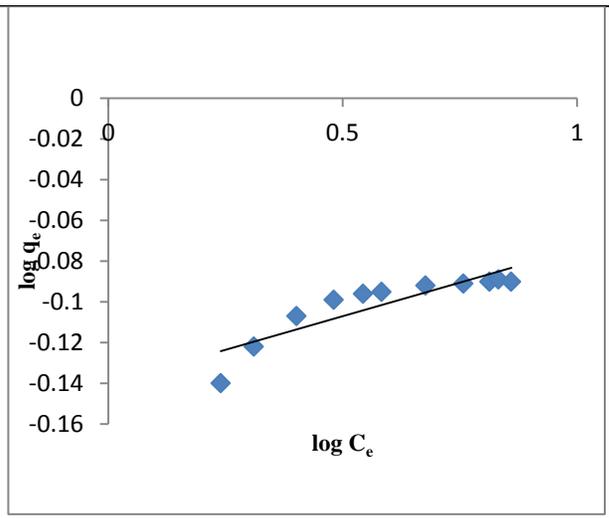


Figure 3(B): Freundlich Isotherm GAC-NLSSS-Bi(III)

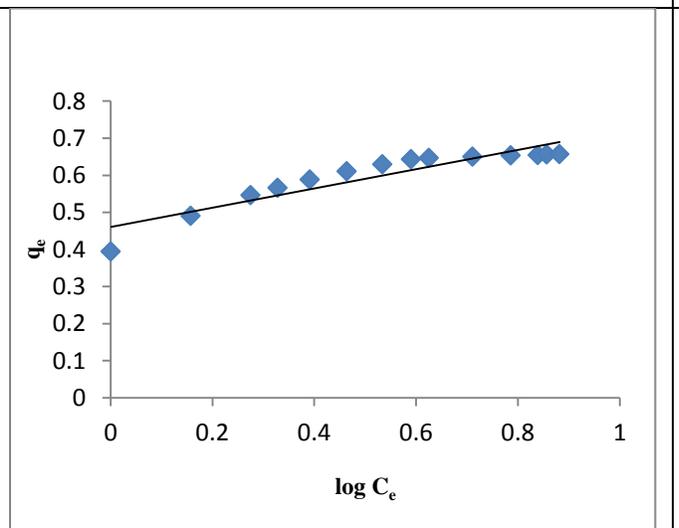


Figure 4(A): Temkin Isotherm GAC-Bi(III)

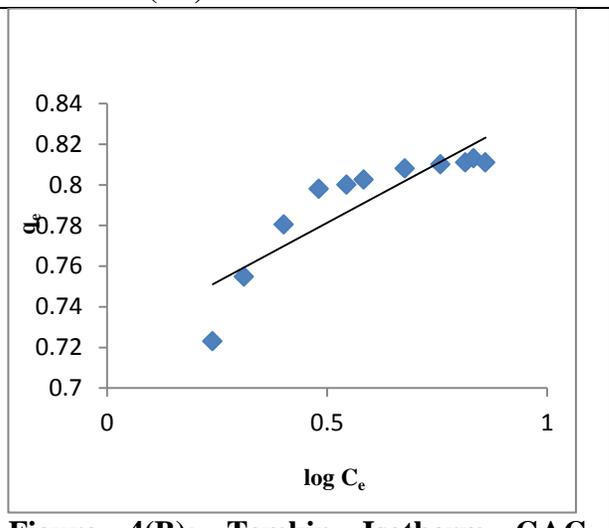


Figure 4(B): Temkin Isotherm GAC-NLSSS-Bi(III)

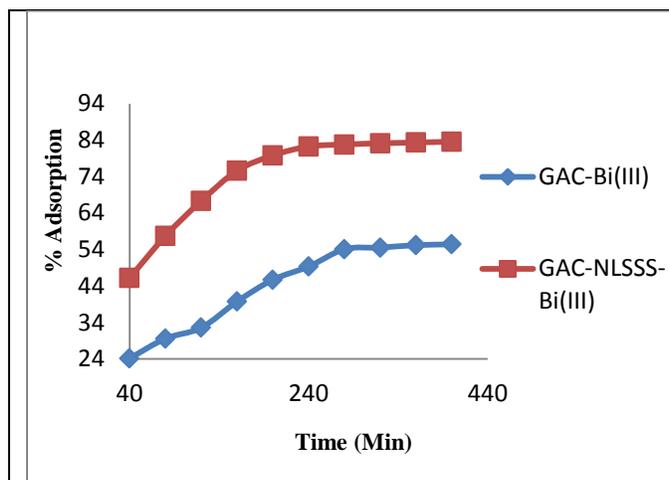


Figure 5: Effect of Contact Time Bi(III)

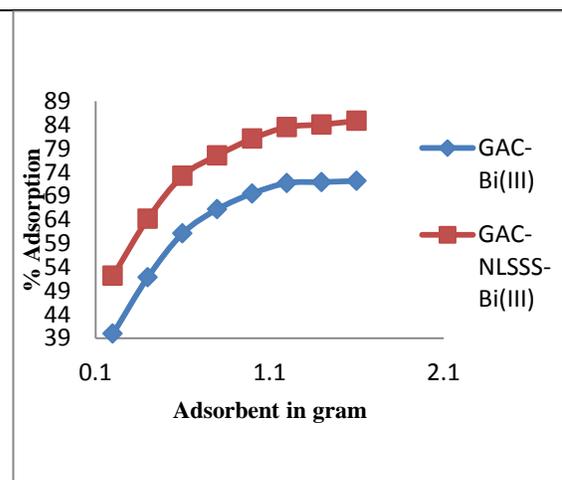


Figure 6: Effect Of Dose Bi(III)

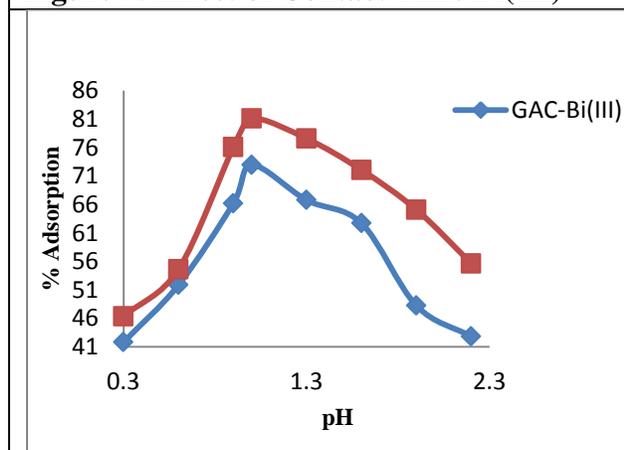


Figure 7: Effect Of pH Bi(III)

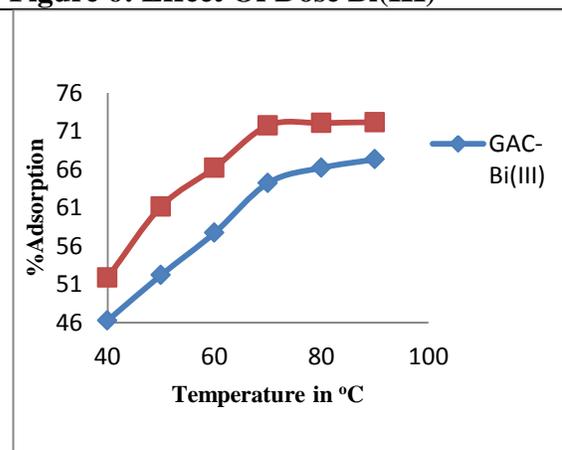


Figure 8: Effect Of Temperature Bi(III)

Table 1: Chemical properties of anionic surfactants used as a ligand in this study.

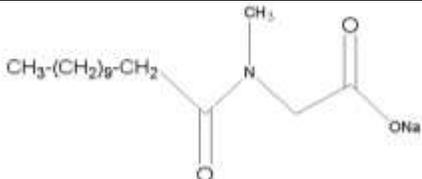
Anionic Surfactant used as a ligand	Structure	Molecular Formula	Molecular weight
N-Lauroylsarcosine sodium salt		C ₁₅ H ₂₈ NNaO ₃	293.38

Table 2: Adsorption Isotherms

Metal ion Bi(III)	Langmuir		Freundlich				Temkin			
	Q ₀	b	R	R ²	K _f	B	R ²	a _t	b _t	R ²
GAC	0.925	0.751	0.128	0.99	0.451	0.28	0.97	0.44	0.150	0.98
	0	8	5	3	8	2	4	6	2	3
GAC-NLSSS	1.694	0.428	0.157	0.97	0.685	0.12	0.92	0.67	0.110	0.93
	9	4	6	1	4	7	1	0		7

CONCLUSION

In the present study we develop a new type of activated carbon capable of removing cationic heavy metal more specifically and effectively. NLSSS most effectively enhanced the activated carbon's capacity to uptake Bismuth (III). The capacity of the GAC to adsorb Bismuth (III) increased in proportion to the quantity of the N-lauroylsarcosine sodium salt with which the activated carbon was impregnated. The maximum removal efficiency was observed up to 81.13% at pH 1.0. The amount of Bi^{3+} ions removed increases with the increase temperature, adsorbent dose, and contact time. The equilibrium data has been analysed using Langmuir, Freundlich and Temkin isotherms. The characteristic parameters for each isotherm and related coefficient of determination R^2 have been determined for experiment at 300 K. The experimental data yielded excellent fits within the following isotherm order: Langmuir > Temkin > Freundlich isotherms based on its R^2 value. The Langmuir produced higher R^2 value for both GAC and GAC impregnated with N-Lauroylsarcosine sodium salt.

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