Research Article

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Adsorption of Ni(II) Ion from Industrial Effluents using a Low-Cost Adsorbent: Kinetic and Optimization Studies

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ABSTRACT

Nowadays, water pollution raises great attention since water constitutes a basic necessity in life and it is essential to all living things. The aim of the present work was to analyze the removal of toxic metal Ni(II) in using available natural adsorbents, namely Tectona Grandis activated carbons. This study was carried out to examine the adsorption capacity of the low-cost adsorbent for the removal of heavy metal Ni(II) from the industrial effluents. The influence of initial concentration, contact time, pH, adsorbent dose, and temperature on the adsorption process was also studied. Results revealed that the adsorption isotherms could be fitted well by the Langmuir model. The R_L values in the present investigation were less than one, indicating the adsorption of Ni(II) ion is favorable in the above adsorbents. Results indicate the freely abundant, locally available, low-cost adsorbent, Tectona Grandis activated carbons can be treated as economically viable for the treatment of metal ions from the industrial effluents.

Keywords: Adsorption; isotherms; low-cost adsorbents; toxic metal

1. INTRODUCTION

Heavy metals are toxic to the ecosystem such that they deserve very high priority concern in the scientific society. These metals have a tendency to bio-accumulate in our biological system, even at micro and Nano levels (Adeolu, *et al.* 2016; Shakthivel *et al.* 2015). Industrialization and urbanization lead to the introduction of heavy metals and other waste pollutants. Large numbers of industries were discharging heavy metals in the form of effluents into the environment in various ways (Braukmann, 1990). These toxic heavy metals were also introduced into the natural water bodies from chemical spills, agricultural run-off, and even municipal wastewater.

Numerous treatments on heavy metal removal from contaminated water have already been applied years ago, which can be divided into chemical, biological, and physical processes. These methods include precipitation, coagulation, filtration, ion exchange, electrodialysis, phytoremediation, bio-mineralization, and adsorption on activated carbon. Recently, the adsorption process has gained interest as a more promising method for the long term as it is seen as a more effective and economical approach for heavy metal removal. The adsorption method is applied mainly for the removal of toxic metals from effluents because of its benefits such as cleaner, cheaper, and more efficiency. In the past, various researchers have tested the applicability and efficiency of agricultural waste as an adsorbent for the removal of heavy metal in wastewater. Some of the cheaply available waste materials include; sugar bagasse (Nasim Ahmed Kham *et al.* 2004), soya bean hulls (Marshall *et al.* 1999), rice husk (Wong *et al.* 2003), etc. The hazardous nature of Nickel (II) ion is linked with its activity as an Agent carcinogen (Periyasamy *et al.* 1995; Yazici *et al.* 2008; Chen *et al.* 2002). In order to assess the ability of activated carbon of *Tectona Grandis* as a low-cost adsorbent, Ni(II) removal has been selected for this present work. This work tested the ability of activated carbon derived from *Tectona Grandis* for the recovery of nickel(II) ions from industrial effluent, including the measurement of optimum conditions such as agitation time, initial metal ion concentration, pH, a dose of the adsorbent, and temperature.

2. MATERIALS & METHODS

2.1. Batch Adsorption Studies

Batch-mode adsorption was investigated by adding 50 mg of adsorbent to 50 mL of the metal solution of various initial concentrations (50 to 250 mg/L) at a definite pH. The experiment was carried out using a mechanical shaker for the period of 80 min and 120 rpm using 250 mL stoppered glass bottle at 30 ºC to 50 ºC. The residual concentration of metal solutions in each sample after adsorption at different times was calculated by UV – visible spectrophotometer.

2.2 Adsorption Isotherms

To determine the quantity of the sorption capacity of the chosen adsorbent for the removal of Ni(II), the most commonly used isotherms are the Langmuir and Freundlich isotherms, along with the Weber-Morris model and hence these were used in this study.

3. RESULTS & DISCUSSION

3.1 Effect of Agitation Time

The amount of the adsorbed metal ion increased as time increases, and after 70 minutes, adsorption becomes almost constant and attains equilibrium. There is no change in adsorption on further increase in contact time. Similar observations were reported by Wang *et al.* 2002 and Okareh *et al.* 2015.

3.2 Effect of Initial Concentration

The initial concentration of the metal has a significant influence on adsorption. The rapid adsorption of Ni (II) using 50 ml after 70 min before it proceeds at a slower rate and attains saturation has been studied Adebowale *et al.* 2009.

3.3 Effect of Adsorbent Dose

The effect of the TGAC doses was studied by varying the amount of adsorbent dose from 50 mg to 400 mg for the initial concentration of 50 mg/L. The maximum removal was noticed at 200 mg.

3.4 Effect of pH

To analyze the effect of pH on the percentage of Ni(II), the pH of the initial solution was varied from 1.0 to 8.0 by adding HCl or NaOH to them. The percentage removal increases as the pH decrease up to 1.0. At pH 1.0, the optimum percentage removal takes place. So remaining experiments were carried out at pH 1.0.

3.5 Effect of Temperature

The adsorption of Ni(II) at different temperatures, namely 30ºC, 35 ºC, 40 ºC, and 50 ºC were studied. The adsorption was found to be decreased with an increase in temperature. This confirms the exothermic nature of this adsorption process.

3.6 Adsorption Isotherm Studies

To determine the quantity of the sorption capacity of the chosen adsorbent for the removal of Ni(II), the most commonly used isotherms are the Langmuir and Freundlich isotherms, and hence these were used in this study.

3.7 Langmuir Isotherm

The feasibility of the Langmuir isotherm can also be expressed in terms of the dimensionless constant, separation factor, R_L. The values are represented in Table -1.

3.8 Freundlich Isotherm

The value of 1/n was 0.6710 mg/L for Ni(II) adsorption. So Freundlich isotherm is suitable for this adsorption. The value of K_f value also indicates the multilayer adsorption was possible. The values are represented in Table-1. This reveals that the activated carbon adsorbent was efficient for the removal of Ni(II).

3.9 Adsorption Kinetics

The kinetic studies were done by using the pseudo-first-order kinetic model, first-order reversible kinetic model, pseudo-second-order kinetic model, and intra-particle diffusion (Wong, K.K., *et al.*2003) models.

3.10 Weber – Morris Model

In this model, a graph is drawn between q_t and $t^{½}$, and the line was passing through the origin. But here, the intercept value indicates the lines were not passing through the origin. This was due to that intra-particle diffusion takes place along with some other process. This may be boundary layer adsorption or instantaneous adsorption.

Table 1. Adsorption Isotherm Constants and Coefficient of (r2) of Adsorbent

Adsorbent	Langmuir isotherm constant			Freundlich isotherm constants		
	Q^o (mgg^{-1})	b (Lg^{-1})	r^2	k (Lg^{-1})	1/n	r^2
TCAC	16.1031	0.0163	0.9879	9.8673	0.6710	0.9719

Table 2. Effect of Contact Time on Ni (II) Removal

S. No.	Contact time t, min	Percentage Removal, %
1	10	34.70
2	20	60.62
3	30	71.64
4	40	80.92
5	50	90.86
6	60	93.29
7	70	94.85
8	80	94.85

3.11 SEM Analysis

The SEM images of both before and after adsorption were taken and given in fig. 1 & 2. From these figures, it is very clear that Ni(II) is getting adsorbed on the surface of the chosen adsorbent, namely, *Tectona Grandis*.

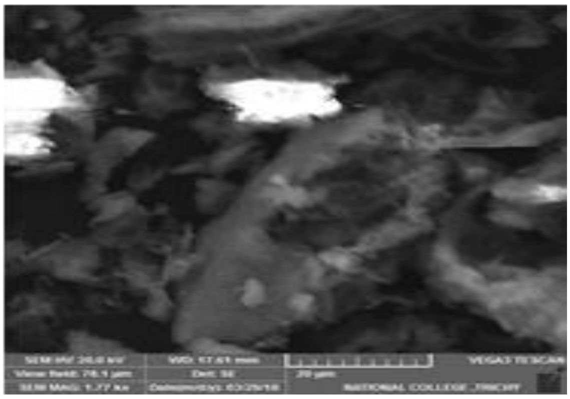

Fig. 1: SEM before Adsorption of Ni (II)

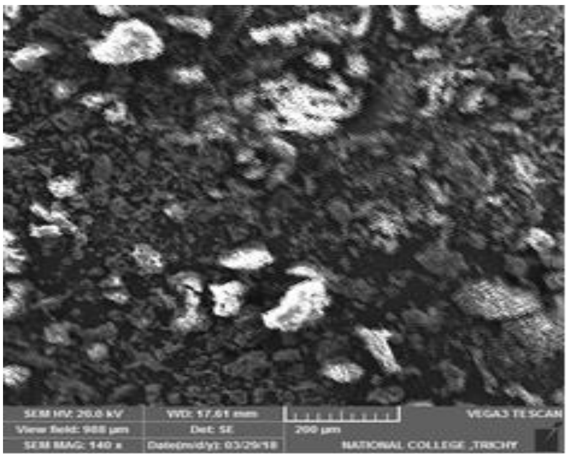

Fig. 2: SEM After Adsorption on Ni (II)

4. CONCLUSION

Batch mode experiments showed that the adsorption process was controlled by contact time, pH, initial concentration of Ni(II), adsorbent dose, and temperature. Adsorption kinetic studies followed the pseudo-second-order kinetics for the chosen adsorbent. The experimental adsorption data were fitted reasonably well to Langmuir adsorption isotherm compared to Freundlich adsorption isotherm. The higher correlation coefficient values obtained for the Weber – Morris equation to the present adsorbate – adsorbent system indicate the importance of intraparticle diffusion in the rate-determining step. The R_L values were calculated, and these were found to lie between one and zero, suggesting that *Tectona Grandis* activated carbon cab be used successfully as an adsorbent for the removal of nickel ions.

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