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Ricinus Communis Pericarp Activated Carbon Used as an Adsorbent for the Removal of Ni(II) From Aqueous Solution

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Abstract: Activated carbon prepared from *Ricinus communis* Pericarp was used to remove Ni(II) from aqueous solution by adsorption. Batch mode adsorption experiments are carried out by varying contact time, metal-ion concentration, carbon concentration and pH to assess kinetic and equilibrium parameters. The adsorption data were modeled by using both Langmuir and Freundlich classical adsorption isotherms. The adsorption capacity (Q_o) calculated from the Langmuir isotherm was 31.15 mg/g of activated carbon at initial pH of 5.0±0.2 for the particle size 125-250 μm.

Keywords: Activated carbon, Metal ion, Adsorption, Kinetics, Isotherms

Introduction

The water pollution is mainly due to organics, inorganics, sediments, radioactive materials and heavy metals. Among these pollutants, the contribution of heavy metals to the environment is of major concern because of its toxicity, bioaccumulation, persistence and non-biodegradable nature. Industrial effluent containing nickel plays an important role in polluting water bodies. Additional potential sources of nickel bearing waste include ceramics, nuclear power plants, cryogenic containers, pollution abatement equipment. Nickel is a potent carcinogen. The contactness of nickel with skin results in painful disease, nickel itch, which is followed by sudden death. Acute poisoning of nickel causes chest pain, tightness of the chest, shortness of breath etc. The toxic nature of nickel to fish, lentil plants, crops and algae was also reported[1]. According to environmental protection agency (EPA), USA, the permissible limits of Ni(II) in wastewater is 1 mg/L and Bureau of Indian Standards is 3 mg/L[2]. Hence, it is essential to remove Ni(II) before discharged into water bodies.

Utilizing the waste material from agriculture and industries can make treatment process economical and solve the solid waste disposal problem. The feasibility of several low cost, non-conventional adsorbents obtained from agricultural and industrial wastes was explored. Research has already been conducted on a wide variety of adsorbents. They include walnut shell, waste Turkish coffee, nut shell exhausted coffee[3], saw dust[4], rice bran, soya bean and cotton seed hull[5] have been investigated to remove nickel(II) from wastewater. The present study deals with the use of activated carbon prepared from *Ricinus communis* Pericarp as an adsorbent for the removal of Ni(II) from aqueous solution. The main aim of this work was to evaluate the feasibility of using *Ricinus communis* Pericarp carbon for Ni(II) removal.

Experimental

Adsorbent

In the present study, Pericarp of *Ricinus communis* used for the preparation of activated carbon. The dried Pericarp was allowed to chemical activation, by the addition of 50% sulfuric acid with constant stirring (w/v). The charred material was kept in hot air oven at 100 ± 5^{o}C for 12h. This was washed with double distilled water and this was soaked in 10% sodium bicarbonate solution and allowed to stand overnight to remove the residual acid from pores of the carbon. The material was washed with distilled water, until the pH of the adsorbent reached 7 ± 0.2. Then it was dried in a hot air oven at 100 ± 5ºC for 12h. The dried material was ground and sieved to get the particle size of 125 - 250 μm. The sieved adsorbent was stored in an airtight container for further experiments. All the chemicals used were of analytical reagent grade obtained from B.D.H and E.Merck. Double distilled water was used for all the experimental studies.

Adsorbate

Ni(II) stock solution (1000 mg/L) was prepared in double distilled water using nickel sulphate. The working solution was obtained by diluting the stock solution in distilled water.

Batch mode adsorption studies

The working solution of 10, 20, 30, 40 mg/L of Ni(II) was prepared from stock solution. Batch mode adsorption studies were carried out with 50 mg of the adsorbent and 50 mL of Ni(II) solution of desired concentration at a pH of 5.0±0.2, agitated at 120 rpm in a mechanical shaker at room temperature. The adsorbate solution was separated from the adsorbent by centrifugation at 3000 rpm and estimated spectrophotometrically at 470 nm using dimethylglyoxime reagent[6]. The effect of carbon dosage on percent removal of Ni(II) was studied with solutions of 30 mg/L for particle size 125-250 μm. Effect of pH on Ni(II) removal was studied for metal ion concentration of 20 and 40 mg/L using 50mg of carbon dosage.Langmuir isotherm study was carried out with different initial concentration of Ni(II) from 5 to 40 mg/L, while maintaining the adsorbent dose at 50 mg/50 mL. Desorption studies was carried out to confirm the adsorption mechanism proposed above and to recover the metals from the adsorbent using 0.025 to 0.350 M hydrochloric acid.

Results and Discussion

Adsorbent characterization

Characteristics of activated carbon prepared from *Ricinus communis* Pericarp are presented in Table 1. The determined surface area of *Ricinus communis* Pericarp activated carbon (RCP) was 495 m^2/g and is comparable to various low cost adsorbents namely, peanut hull carbon[7](208 m^2/g), eichhornia[8] (200 m^2/g), cassava[9](200 m^2/g) and coconut tree saw dust carbon[10](325 m^2/g). The moisture content of the carbon was found to be 2.50% (Table 1). This would not influence the adsorptive power of activated carbon. It was then observed from the literature that if the moisture content of the adsorbent is more, it will dilute the action of activated carbon and it necessitates utilizing some extra load of carbon[11]. The iodine number and decolorizing power were 468 g/g and 21.0 mg/g respectively which indicates that the carbon prepared by acid activation method has good adsorption capacity and it can be considered for adsorption of organic dyes. The surface morphology of activated carbon (RCP) was visualized via scanning electron microscopy (SEM), the corresponding SEM micrographs being obtained using a JSM-840 JEOL microscope of JEOL Techniques LTD, Japan at 2000x magnification (Figure. 1). Examination of SEM micrographs of the RCP particles showed rough areas of the surface of the carbon and the microspores were identifiable. The activation process of RCP by adopting sulphuric acid treatment leads to corrode the surface of carbonaceous material and introduce micro, macro and mesopores.

Table 1. Characteristics of activated carbon

Parameters	Value
pH 1 % solution	6.90
Moisture content, %	2.50
Ash content, %	6.50
Decolorizing power, mg /g	21.00
Ion – exchange capacity, equi g	0.80
Determination of surface area, m^2/g	495
Bulk density, gm /L	0.46
Porosity, %	68.27
Specific gravity	1.46
Particle size, μm	125-250
Iodine number, mg/g	468
Yield , %	70
Calcium, mg/ g	20.0
Sodium, mg / g	28.8
Potassium, mg /g	2.3
Water – soluble matter, %	1.29
HCl soluble matter, 0.25 N, %	2.45

Effect of agitation time on Nickel(II) adsorption

The effect of agitation time on the percent removal of Ni(II) by RCP carbon is shown in Figure 2. The percent removal increases with increase in agitation time and attains equilibrium within 70 mts for all the concentrations studied (10 to 40 mg/L). The curves were single, smooth and continuous till the saturation of Ni(II) on activated carbon surface.

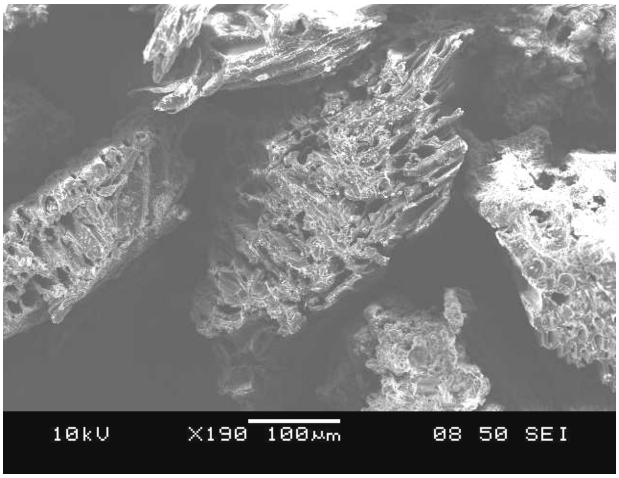

Figure 1. SEM Photograph of the RCP carbon

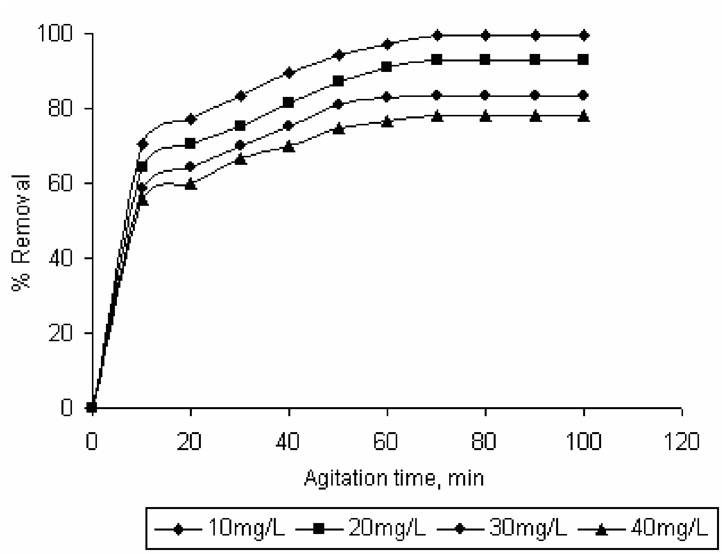

Figure 2. Effect of agitation time and initial Ni(II) concentration on Ni(II) adsorption

Adsorption kinetics

The adsorption kinetics of Ni(II) on adsorbent follows first order rate expression given by Lagergren[12].

$$\log_{10}(q_e - q) = \log_{10} q_e - K_{ad}\, t / 2.303$$

Where, K_{ad} (1/min) is the rate constant of adsorbent, q and q_e are the amount of Ni(II) adsorbed (mg/g) at time t (min) and equilibrium time. Linear plots of $\log_{10}(q_e – q)$ *versus* t (Figure 3) shows the applicability of above equation. The K_{ad} values for different Ni(II) ion concentrations of 10, 20, 30 and 40 mg/L calculated from the slope of the plots were 0.0504,0.0511,0.0732 and 0.0564 1/min respectively.

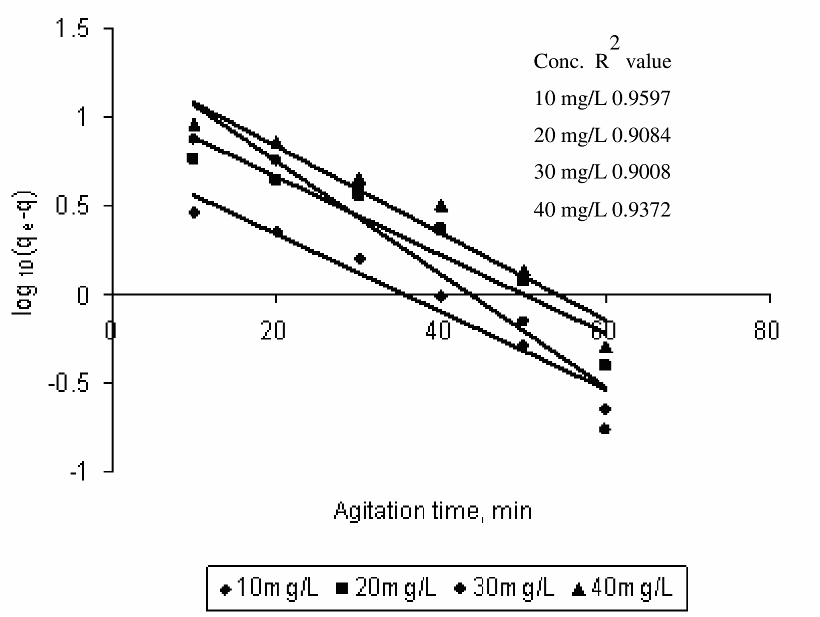

Figure 3. Lagergren plots for Ni(II) adsorption

Effect of adsorbent dosage on Nickel(II) adsorption

The effect of carbon dosage on percent removal of Ni(II) is shown in Figure 4. When the carbon dosage increases, the percent removal also increases. It was found that for the removal of Ni(II) of 30 mg/L, the maximum adsorbent dosage of 80 mg/50 mL was required. Increasing adsorbent dosage increases the removal because of availability of more surface area and functional group.

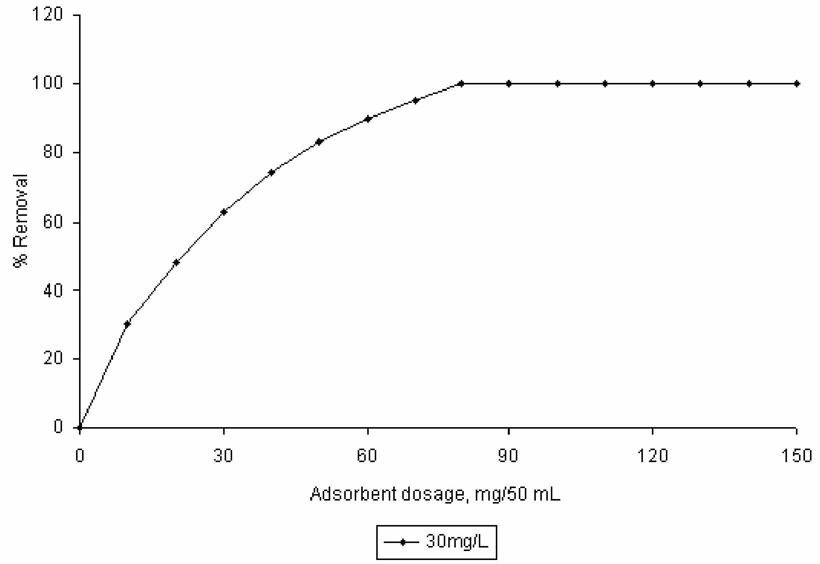

Figure 4. Effect of carbon dosage on Ni(II) adsorption

Adsorption isotherms

The Langmuir isotherm can be applied for adsorption equilibrium of Ni(II) onto RCP carbon[13]

$$C_e / q_e = 1/Q_{ob} + C_c / Q_o$$

Where, C_e is the equilibrium concentration (mg/L), q_e is the amount of Ni(II) adsorbed (mg/g), Q_o and b are Langmuir constants related to adsorption capacity and energy of adsorption respectively. The linear plot of C_e / q_e *versus* C_e (Figure 5) shows that the adsorption follows Langmuir isotherm where Q_o = 31.15 mg/g and b = 1.7262 for 5- 40 mg /L concentration. Langmuir isotherm can be expressed in terms of dimensionless separation factor of equilibrium parameter

$$R_L = (1 / 1+bC_o).$$

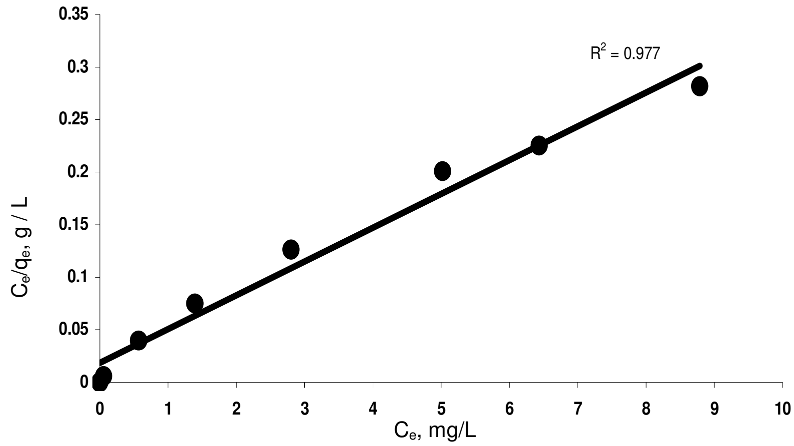

Figure 5. Langmuir plot for Ni(II) adsorption

Where, C_o is the initial Ni(II) concentration (mg/L) and b is the Langmuir constant (L/mg). R_L values for different Ni(II) ion concentration (Table 2) was found to be between 0 to 1 indicate favourable adsorption of Ni(II) on to RCP carbon. The linear form of Freundlich equation can be given by, $\log_{10} (X/m) = \log_{10} K_f + 1/n \log_{10} C_e$

Table 2. Analysis of langmuir isotherm for Ni(II) adsorption

S. No.	Initial Ni(II) Concentration, mg/L	R_L	Q_0, mg/g	B, L/mg
1	5	0.1038	31.15	1.7262
2	10	0.0547		
3	15	0.0371		
4	20	0.0281		
5	25	0.0226		
6	30	0.0189		
7	35	0.0162		
8	40	0.0142		

Where, X is the amount of Ni(II) adsorbed at equilibrium (mg), m is the weight of adsorbent used (mg), C_e is the equilibrium concentration of Ni(II) in solution (mg/L), K_f & n are constants. Linear plot of $\log_{10}$ x/m *versus* $\log_{10} C_e$ show that the adsorption follows Freundlich isotherm (Figure 6). The Freundlich constants K_f and n are found to be 16.850 and 3.561 respectively for 5-40 mg / L concentration.

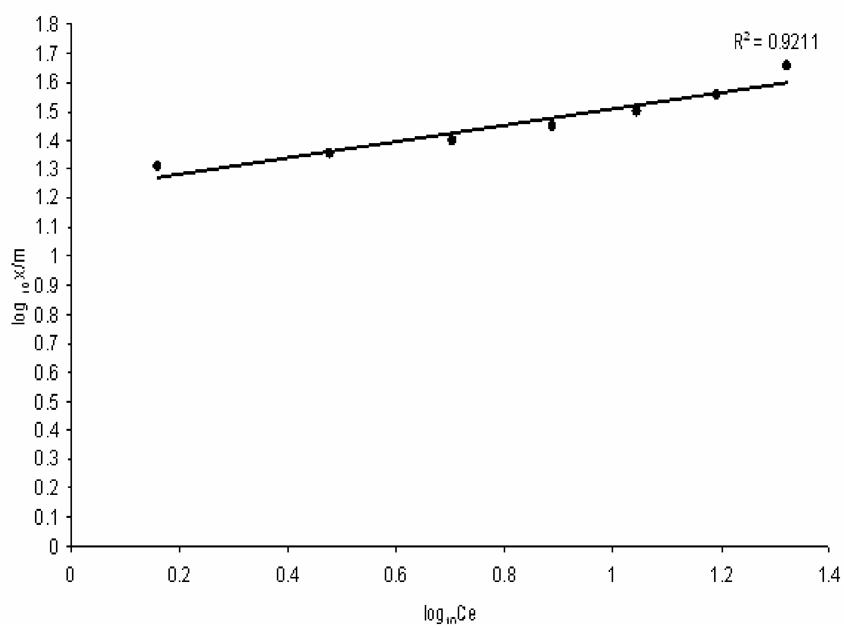

Figure 6. Freundlich plot for Ni(II) adsorption

Effect of pH on Nickel(II) adsorption

The effect of pH from 2.0 to 10.0 was studied to remove nickel(ii) ions from the aqueous solution with adsorbent (Figure. 7). The precipitation was observed from the results at pH 6.0 onwards and the intensity of precipitation increases with the increase in pH from 6.0 to 10.0. Similar observations were reported for coir pith carbon[14] .The removal of metal ions increases with increase in pH from 6 .0 to 10.0 even without adsorbent, this is may be due to the formation of metal hydroxide precipitation.

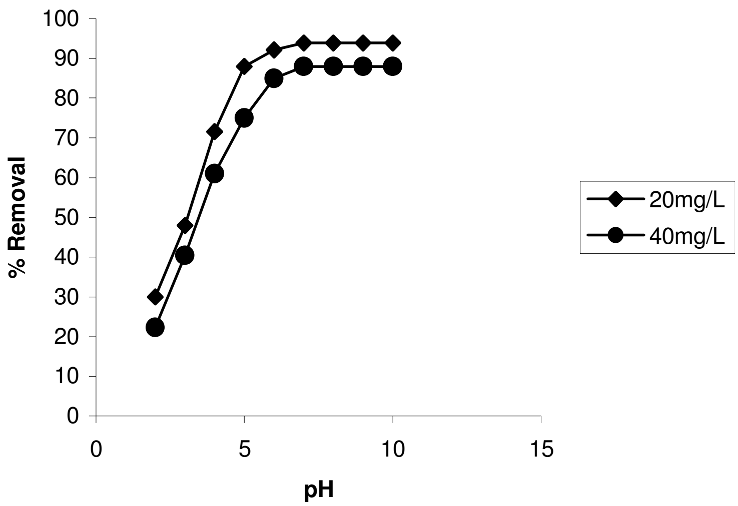

Figure 7. Effect of pH on Ni(II) adsorption

Desorption studies

Desorption studies was carried out to confirm the adsorption mechanism proposed above and to recover the metals from the adsorbent. The quantitative recovery of metal ion indicated that regeneration of carbon was possible. This is further evidence that ion exchange is involved in the adsorption mechanism. Desorption was carried at different concentration of hydrochloric acid (0.025-0.350 M).The results are shown in Figure 8. Maximum desorption occurs at the strength of 0.325 M.

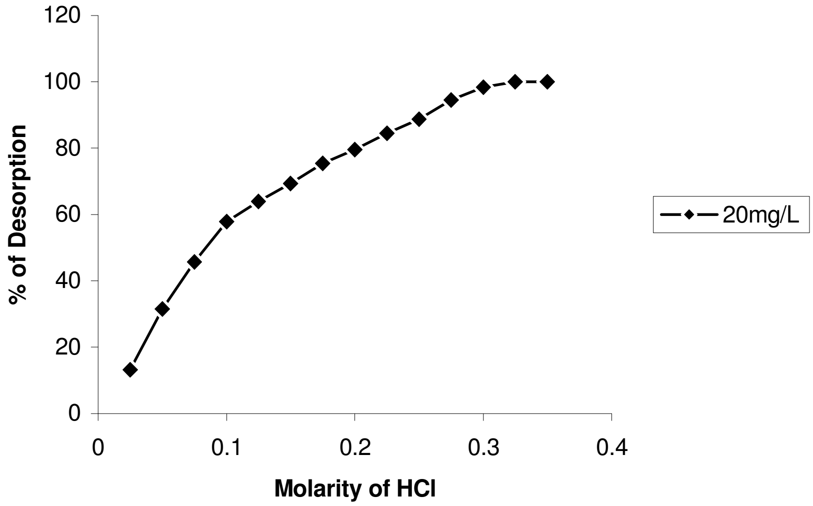

Figure 8. Desorption of Ni(II) ions from RCP carbon

Conclusion

The current investigation shows that *Ricinus communis* Pericarp carbon is very effective adsorbent in removal of Ni(II) ions from aqueous solution. Increase in adsorbent dosage and agitation time increases Ni(II) ion removal at the optimum pH of 5±0.2.The adsorption followed both Langmuir and Freundlich isotherm models. The desorption studies reveals that recovery of Ni(II) ions from adsorbent is possible.

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