Coconut leaves as a low cost adsorbent for the removal of Nickel from Electroplating effluents

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Abstract— This study was focused on coconut leaves as an alternative adsorbent for the removal of Ni(II) from wastewater. Batch experiments were conducted at room temperature 27^{0}C to determine the factors affecting adsorption of Ni(II). The adsorption process is affected by various parameters such as contact time, solution pH, adsorbent dose and initial concentration. The maximum removal efficiency of Ni(II) was 93.18% for 2.0g/50ml of coconut leaves at pH 8.0 in optimum time of 4 hours. The experimental data was tested using Langmuir and Freundlich equations. The data fitted well to both Langmuir and Freundlich isotherms. The adsorption kinetics were best described by the pseudo second order model. The cost of removal is expected to be quite low, as the adsorbent is cheap and easily available in large quantities. The present study showed that coconut leaves was capable of removing Ni(II) from aqueous solution.

Key words: Adsorption, Coconut leaves, Nickel(II).

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1 Introduction

In India, there are more than 50,000 large, medium, and small scale electroplating units mostly scattered in urban areas[2] and there are about 79 electroplating industries located in Karnataka state, out of which 71 industries are in and around Bangalore city only[3]. The water consumption is less in electroplating industries compared to other industries, and the effluent is more toxic than other wastes. These industries produce toxic hazardous waste containing heavy metals approximately 78,000kg/annum which adversely effect environment, especially humans, animals, plants, and aquatic life [3].

When waste water containing heavy metals flows on the surface of the ground, it looses fertility and the waste water containing nickel, originates primarily from metal industries, particularly during plating operations. Occurrence of dermatitis in some workers engaged in electroplating, polishing paints and pigments may be attributed to nickel poisoning.

Heavy metal toxicity can result in damage or reduced mental and central nervous function, lower energy levels and damage to blood composition, lungs, kidneys, liver and organs[4].

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Heavy metals can pose health hazards, if their concentration exceeds allowable limits[5]. Therefore, before waste water flows through waterbodies or land, it should be treated.

Effluents from industrial processes such as electroplating, mining, nuclear power operation, battery manufacturing, dye and pigment have been identified to contain high level of heavy metals, such as Cr(III), Cr(VI), Zn, Cd, Cu, Ni, Hg and Pb [6].
The methods adopted are ion exchange, electrochemical reduction, evaporation, solvent extraction, reverse osmosis, chemical precipitation, membrane filtration, and adsorption[7].
Many researchers have identified the low cost adsorbent like saw dust [8], rice husk [9], coir pith[10], coconut shell, waste tea powder, coconut husk[11], sugar cane bagasse [12] and others.

Even though the industries are not keen to adopt these adsorbents, all industries are adopting chemical processes only, due to difficulty in disposing of adsorbent materials after use.

Therefore, it is important to identify an adsorbent material like coconut leaves for removal of heavy metals in electroplating industrial effluents which is having advantages of removal of pollutants from effluents effectively and do not have much adverse impact on environment when disposed after treatment. The main objective of the experiment is to remove the Ni(II) from waste water using low cost and locally available adsorbent material and alternative treatment method.

2 MATERIALS AND METHODS

Coconut leaves (adsorbent): Coconut is one of the important pereninal crops belonging to Palmae.Botanically, it is known as 'cocos nuciferra.L'. Leaves are pinnate and are called 'fronds', which are generally 4 to 6 meters in length and 1.5 to 2 meters in width. Leaves have a strong rachis to which the leaflets are linear-lanceolate. Canopy of coconut (crown) consists of 28 to 36 fronds at the tip of the stem arranged in circular shapes. Generally, one frond is added to the canopy every month and one frond is abscessed from the stem.

Table 1
Physical constants of Coconut leaves

Density	0.117g/cm^3
Surface area	0.23921cm^2/g
pH	6.02

(Tested in B.I.T. laboratory)

Table 2
Chemical composition of Coconut leaves

Parameter, mg/l, Max	%
Moisture	8.45
Potasium oxide (K_2O)	0.46
Phosporous oxide(P_2O_5)	0.25
Calcium oxide(CaO)	0.28
Magnesium oxide(MgO)	0.29
Loss of iginiton	86.10
Silicon dioxide(SiO_2)	10.98
Aluminum dioxide (Al_2O_3) +Iron oxide (Fe_2O_3)	1.18

(Tested in Civil Aid, Bangalore- 2011)

Preparation of adsorbent: Coconut leaves were obtained from Mandya district. These leaves was washed with distilled water, dried, and powered. These powered leaves were sieved with IS sieves (1000-600µ). Sieved samples was washed with distilled water and dried at room temperature 27^{0}C for 24 hours, and then samples was dried in hot air oven at a temperature 42^{0}C for 8 hours and later cooled in room temperature and preserved in air tight plastic container.

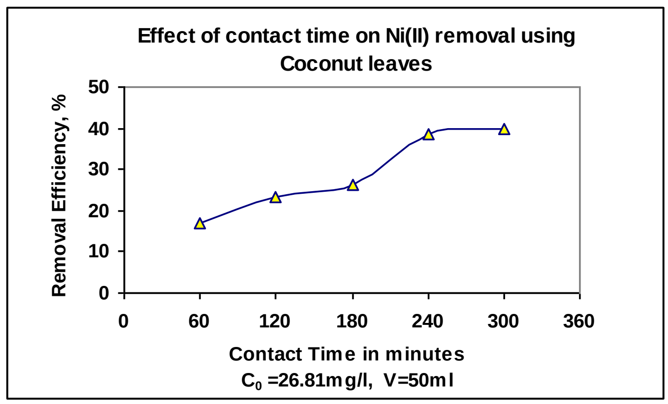
Instruments and Reagents: Chemito AA-203 Atomic Adsorption Spectro photometer was used for the determination of Ni(II), 250ml Erlenmeyer flasks, digital pH meter and 2000 rpm centrifuge model of rotary shaker was used for agitating the mixture of Effluent and adsorbent.

A **stock solution** containing 1000mg/l of Ni (II) was prepared by dissolving the pure nickel metal in 1:1 hydrochloric acid solution and then diluting the same up to 1000ml in a volumetric flask with double distilled water.

Batch Experiments: Batch equilibrium adsorption experiments were conducted by adding known quantity of coconut leaves to Erlenmeyer flasks containing 50ml of industrial effluent at different concentrations of Ni(II) at pH 2.42. Initial pH of the solution was adjusted using dilute 0.1M HCl or 0.1M NaOH. The flasks were agitated 150rpm in a rotary shaker. The experiments were conducted for contact time of one to five hours and pH ranging from 2 to 12 respectively. Initial concentration of Ni was 26.81mg/l. The adsorbent was separated from the solution by filtration. The removal efficiency of Nickel(II) using Chemito AA-203 Atomic Adsorption Spectro Photometer depending upon the wavelength (357.48nm) and working standards. The percentage removal efficiency (η) and equilibrium concentration were determined.

3 RESULTS AND DISCUSSION

a. Effect of Contact Time on Ni(II) removal by coconut leaves

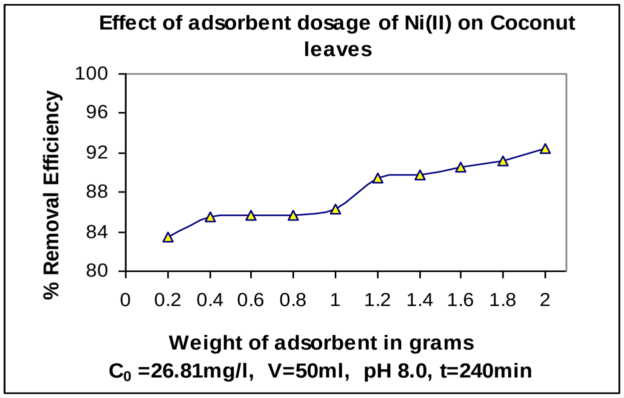


Fig(1)

The results for the effect of contact time on adsorption of Nickel (II) removal are shown in **Fig(1)**. 0.2 to 2.0g of adsorbent was used for this experiment in contact time 60 minutes to 300 minutes. The percentage removal efficiency of nickel (II) ions increases with increase in contact time. The equilibrium contact time was established at 240minutes as shown in **Fig(1)** which was used as optium contact time for further tests.

At the initial stage, the rate of removal of Ni(II) was higher due to availabilty of more number of active sites on the surface of the adsorbent and became slower after 240minutes, due to decreased or lesser number of active sites. Similar observation has been reported in literature [13].

b. Effect of adsorbent dosage on Ni(II) removal using coconut leaves

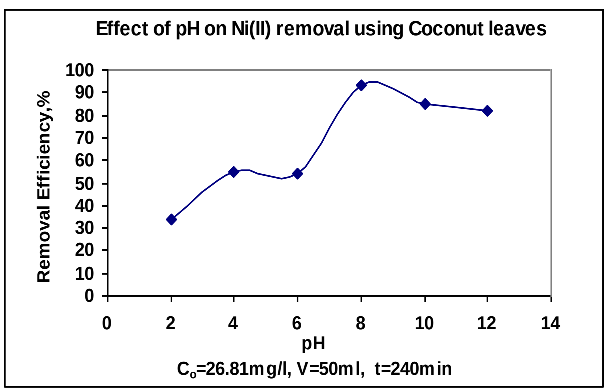


Fig(2)

The results for the effect of weight of adsorbents on adsorption of Nickel (II) removal using Coconut leaves are shown in fig (2). 0.2 to 2.0g of Coconut leaves were used in this experiment for removal of Ni (II).

The percentage removal adsorption increased as the adsorbent dosage is increased. This shows that by increasing the adsorbent dosage the efficiency of coconut leaves increases, while adsorption density decreases with increase in adsorbent dosage. The decrease in adsorption density may be due to the fact that some adsorption site has remained unsaturated during the adsorption process whereas; the number of sites for adsorption increased by increasing the adsorption dosage and that resulted in the increase of removal efficiency. Similar observations are reported in literature [4], [6], [14].

c. Effect on pH on Ni(II) removal using coconut leaves



Fig(3)

The adsorption capacity of adsorbent as function of effluents pH was 2.42. The experiment was conducted over pH range of 2 to 12. pH is one of the most important parameters controlling the adsorption process. The effect of pH of the solution on the adsorption of nickel ion on coconut leaves was determined. The pH of solution was controlled by the addition of 0.1M of HCL or 0.1M of NaOH.The uptake of the nickel ions at pH 8 was maximum and at pH 2 was minimum and slightly decreases at pH 10-12 as shown in fig (3). At low pH values, the adsorption percentage is low due to the positive charge density (protons) on the surface sites, resulting in the electrostatic repulsion between the Ni(II) ions and edges groups with positive charges ($Si\text{-}OH^{2+}$ or $Ca\text{-}OH^{2+}$) on the surface. Electrostatic repulsion decreases with increasing pH because of reduction of positive charges density on the sorption edges, thus resulting in an increase in Ni(II) ion adsorption on the surface.

In an Alkaline medium, the surface of coconut leaves becomes negatively charged. Refering to **Fig(3)**, the maximum adsorption of Ni(II) ion occurred at pH 8. At pH values higher than 8, Ni(II) precipitated as hydroxide which decreased the rate of adsorption and subsequently the percent removal of Ni(II) ions. Similar observation was reported in literature [15].

d. Effect on initial concentration on Ni(II) removal using coconut leaves

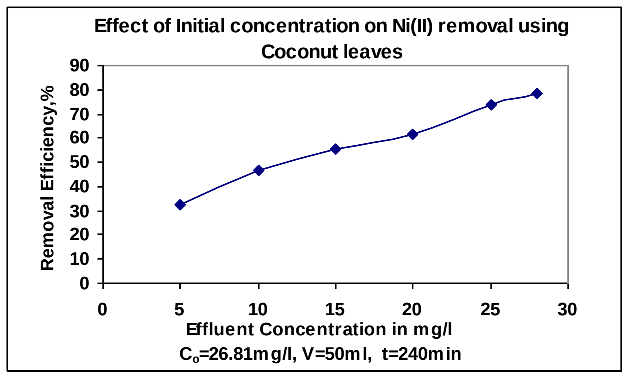
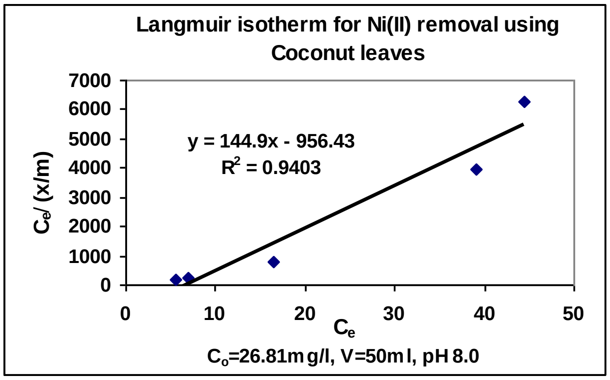


Fig (4)

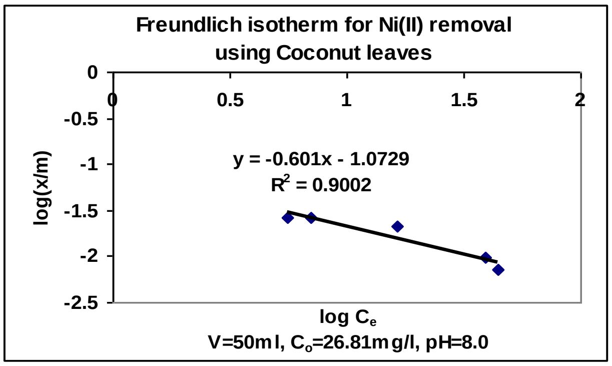
The experiment was carried out over initial concentrations 5mg/l to 26.81mg/l per 50ml of solution and at a contact time of 1-5 hours with 0.2 to 2.0g of coconut leaves with a pH of 2.42. The minimum and maximum removal efficiency of nickel is 32.702% and 78.41% respectively as shown in **Fig(4)**.

The experimental results of adsorptions of nickel ion on the electroplating effluent at various concentration (5, 10, 15, 20 and 26.81mg/l) with contact time of 4hours as shown in **Fig(4)**.It revelead the adsorption capacity increased with increase in the Ni(II) concentration. This was due to higher probabilities of collusion between metal ion and adsorbent. Similar observation was reported in literature [16].

e. Langmuir isotherm and Freundlich isotherm for coconut leaves



Fig(5)



Fig(6)

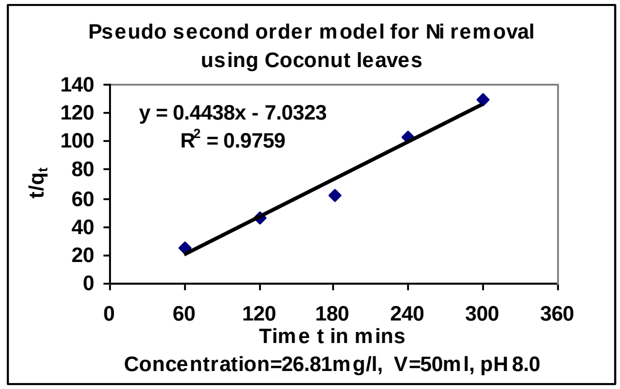
Several equilibrium models have been developed to describe adsorption isotherm relationships. The adsorption of Ni(II)ions was carried out at different initial concentrations ranging from 5 to 26.81 mg/l with contact time 4 hours. The data obtained were analyzed with the Langmuir and Freundlich isotherm equations as shown in **Fig (5 and 6).**

The meanvalues of the regression co-efficient (R^2) is found to be 0.9383 and 0.8242 in Langmuir and Freundlich isotherm equations respectively. The result shows that the experimental data best suits Langmuir isotherm than the Freundlich isotherm. The results are shown in the table (3).

Table 3

Weight of adsorbent in grams/50ml	Langmuir Isotherm	
	Equation from Graph	R^2 value
0.2	y = 13.708x-62.342	0.9518
1.0	y= 62.567x-409.83	0.9229
2.0	y = 144.9x -956.43	0.9403
Freundlich Isotherm		
0.2	y = -0.4047x-0.3235	0.7741
1.0	y = -0.4605x-0.9068	0.7984
2.0	y = -0.601x-1.0729	0.9002

f. Pseudo second order kinetics for Ni(II) using coconut leaves



Fig(7)

The equilibrium adsorption study of Nickel(II) was done to study the kinetics of the reaction involved. Using experimental data, the pseudo first order (figure not shown) and second order model are drawn as shown in **Fig (7).**

It was found that mean value of Regression co-efficient (R^2) is 0.3477 for pseudo first order equation and 0.9228 for pseudo second order equation. The data confirms the pseudo second order reaction and results are shown in table (4).

Similar observations reported in literature [4].

Table 4
Adsorption kinetics for Pseudo first and second order

Concentration in mg/l	Pseudo first order equation	R^2 value
05	y = -0.0005x+1.8678	0.7827
10	y= -0.0007x+2.1619	0.8288
15	y= -0.0003x+1.8686	0.1033
20	y= 8E-06x+2.4372	0.0036
26.81	y= -8E-05x+1.1789	0.0201
Concentration in mg/l	**Pseudo second order equation**	**R^2 value**
05	y = 0.0934 x – 0.4935	0.9055
10	y = 0.0355x +1.2813	0.9309
15	y = 0.0497x+3.3276	0.8710
20	y = 0.0271x-0.0248	0.9308
26.81	y = 0.4438x-7.0323	0.9759

4 CONCLUSIONS

The adsorption behaviour of Nickel on coconut leaves was investigated in batch equilibrium adsorption. The adsorption was found to be drastically dependent on pH, adsorbent dosage and contact time. The optimum pH for Ni ion was found to be 8. The rate of Ni adsorption was rapid using coconut leaves with equilibrium contact time of 4hours.

Isotherm analysis of the data showed that, the adsorption pattern of Ni(II) followed by the Freundlich isotherm equations. The maximum adsorbent dosage was 2.0g/50ml, used for treatment of electroplating effluent. Kinetics data is confirmed with Pseudo second order reaction rate model.

References

[1] APHA, Standard methods for the examination of water and wastewater, 21st ed., APHA, AWWA, WPCF, Washington, D.C, 2005.

[2] R.P.Singh, N.Gupta, R.Suman and Radha Gupta,"Removal of Heavy meatals from Electroplating Effluents by Carbonized agro-wastes",*School of Chemical Sciences*, Agra.

[3] "Inventory of Hazardous Waste Karnataka state 2007"_ *Karnataka State Pollution Control Board*.

[4] H.Zavvar Mousavi, S.R.Seyedi, "Nettle ash as a low cost adsorbent for the removal of nickel and cadmium from waste water", *International Journal of Environ. Sci. Tech,* 8(1), 195-202, 2011.

[5] S.Y.Quek, DAJ Wase and CF Forster-"The use of sago waste for the sorption of lead and copper", *Birmingham University*, 24(3), 251-256, 1998.

[6] K.O.Olayinka, B.I.Alo and T.Adu-"Sorption of heavy metals from Electroplating effluents by low cost adsorbents II: Use of waste Tea, Coconut shell and Coconut husk", *Journal of Applied Science*, 7(16),2307-2313, 2007.

[7] Nasim Ahmad Khan, Md. Ghazaly Shaaban and MohdHasruddin Abu Hassan, "Removal of Heavy metal using an inexpensive adsorbent", *University Malaya* 2003.

[8] T.P.Dhungana and P.N.Yadav, "Determination of Chromium in Tannery Effluent and study of Adsorption of Cr(VI) on Sawdust and Charcoal from Sugarcane Bagasses", *J.Nepal Cem. Soc.*, 23, 93-101, 2008/2009.

[9] Srinivasan K. Balasubramaiam N. and Ramakrishna T.V., "Chromium Removal by Rice Husk Carbon", *Indian Journal Environmental Health*, 30(4), 376-387, 1998.

[10] ParindaSuksabye, PaitipThiravetyan and WorananNakbanpote-"Treatment of chromium contaminated wastewater by coconut coir pith"_ King Mong's University of Technology, Bangkok.

[11] O.Olayinkakehinde, T.Adetunde Oluwatoyin, and O.Oyeyiola Aderonke, "Comparative analysis of the efficiencies of two low cost adsorbents in the removal of Cr(VI) and Ni(II) from aqueous solution", *African. Journal of Environmental Science and Technology*, 3(11), 360-369, 2009.

[12] Khan N.A., Ali S.I and Ayub S., "Effect of pH on the Removal of Chromium (Cr) (VI) by Sugarcane baggasse", *Science and Tech*., 6, 13-19, 2001.

[13] N. Kannan and T.Veemaraj, "Detoxification of toxic metal ions by sorption onto activated carbon from Hevea Brasiliensis bark- A comparative study", Global NEST Journal, 12(2), 197-205, 2010.

[14] Mohammad Ajmal, R.A. K. Rao, Jameel Ahmad and Rais Ahmad, "The Use of Testa of groundnut Shell (Arachis hypogea) for the Adsorption of Ni(II) from the Aqueous system", Journal of Environ. Science & Engg, 48(3), 221-224, 2006

[15] M.Torab-Mostaedi, H.Ghassabzadeh, M. Ghannadi-Maraghesh, S.J.Ahmadi and H.Taheri, "Removal of Cadium and Nickel from Aqueous solution using expanded perlite", *Brazilian Journal of Chemical Engineering*, 27(02), 299-308, 2010.

[16] B.Thirunavukkarasu and K. Palanivelu-"Biosorption of Cr(VI) from plating effluent using marine algal mass"_ Indian Journal of Biotechnology, 6, 359-364, 2007.

[17] Iman. Y. El-Sherif, A. Ashmawy and S. Badr, "Biosorption of Cadmium and Nickel by Nile Water algae", Journal of Applied Science Research, 4(4), 391-396, 2008.