# Nickel Removal By Adsorption Using Oil Palm Fibre



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## ABSTRACT

Nickel (Ni) is present in wastewaters of a number of industries e.g. steel, electroplating, batteries manufacture, etc. Conventional heavy metal removal technologies such as ion exchange, chemical precipitation, reverse osmosis, etc. are often ineffective or expensive. Adsorption is a commonly used method for the removal of heavy metals from aqueous solutions. However, for the process to be economical, the adsorbent should be easily and cheaply available in abundance and it should require minimal pre-treatment; for expensive pre-treatment procedures would add to the overall treatment cost. This work describes the use of a locally available low cost adsorbent, oil palm fibre, for the removal of Ni from aqueous solution. The oil palm fibre was obtained from a local palm oil factory and was treated with concentrated sulphuric acid prior to its use as adsorbent. A series of batch studies, using 250 ml Erlenmeyer flasks and an orbital shaker, was conducted to evaluate the effect of agitation time, pH and adsorbent mass on the removal of Ni. Isotherms were generated to describe the removal of the metal. The results show that the treated fibre was an effective adsorbent for the removal of Ni. The optimum agitation time and optimum pH were 90 minutes and 7 respectively. The Ni adsorption pattern followed the Freundlich isotherm closely.

## KEYWORDS

Low cost, adsorption, nickel, oil palm fibre.

## INTRODUCTION

Heavy metals contamination of water and wastewater is a common phenomenon. Industrial wastewaters are usually the cause of heavy metals pollution of the environment. Heavy metals can bring about serious water pollution problems and threaten ecosystems. Thus, it is essential to limit their discharge into the environment. Efforts are, therefore, constantly being made to develop new or modify existing technologies for their removal from effluents before their discharge into receiving water bodies.

Traditional technologies for heavy metals removal include ion exchange, chemical precipitation and reverse osmosis. These methods are often ineffective or expensive, particularly for the removal of heavy metal ions at low concentrations. Hence there is a need for the development of efficient and environmental friendly waste treatment technologies to reduce the heavy metals content in wastewaters to acceptable levels at inexpensive costs.

The present study focuses on the removal of nickel (Ni) from aqueous solution. Ni is a naturally occurring hard, silvery-white metal. Its widespread industrial applications such as nickel plating and making of steel, coins, jewellery, batteries and heat exchangers have resulted in its presence in many industrial effluents. Ni is an essential micronutrient, but with prolonged contact and at high doses it can cause skin allergic reactions, asthma, bronchitis, lung & heart disorders and adverse effects on stomach & blood. Some nickel compounds are carcinogens and metallic nickel may possibly be carcinogenic to humans. Hence it is necessary to reduce Ni from water/wastewater to acceptable levels.

Malaysia is at present the largest producer and exporter of palm oil in the world. According to the Malaysian Palm Oil Board (MPOB, 2004), at present Malaysia has 3,802,040 hectares of land planted with oil palm. Of this area 3,303,133 hectares are mature and 498,907 hectares are immature. The total crude palm oil (CPO) production in 2003 was over 13.35 million tonnes; 12.14 % higher than that in 2002. This increase in yield, however, also resulted in a concomitant increase in agricultural wastes such as palm oil wastewater sludge and empty fruit bunches (EFB). For example, in 2003 the fresh fruit bunches yield was 18.99 tonnes per hectare of which about 45 % would end up as mill residue in the form of EFB, shell and fibre. This waste is usually incinerated. The main aim of the present study was to determine the feasibility of using an easily available low cost material i.e. oil palm fibre, as adsorbent in the removal of Ni from aqueous solutions. For an adsorption treatment process to be truly low cost not only should the adsorbent be easily and cheaply available in abundance but it should also require minimal or no pre-treatment; for expensive pre-treatment procedures would increase the overall treatment cost.

Recently many researchers have concentrated their work on the identification of low cost, unconventional adsorbents for the treatment of wastewater. Agricultural wastes or derivatives have often been used as adsorbents to mitigate pollution. Some recently studied low cost adsorbents include saw-dust (Zarra, 1995), apple residues (Lee et al., 1998), leaves (Gardea-Torresday et al., 2002), ash (Isa et al., 2004), etc. The abundance and availability of agricultural by-products make them good sources of adsorbents (Bansode et al., 2003).

The objectives of the present study were to determine the agitation time and optimum pH required for the effective removal of Ni from aqueous solutions using treated oil palm fibre. Isotherms were generated to obtain an adsorbent-adsorbate relationship that would describe the removal of Ni.

## MATERIALS AND METHODS

### Materials

The EFB fibre was obtained from the Palm Oil Research Institute of Malaysia (PORIM). The pre-treatment of the fibre was carried out following the procedure outlined by Garg et al. (2004). Accordingly, one part of the dried fibre was mixed with one part of concentrated sulphuric acid and heated in a muffle furnace at 150 °C for 24 h. The material was cooled, washed with distilled water five to six times and soaked in 1% sodium bicarbonate solution overnight to remove residual acid. The treated fibre was then dried in an oven at 105 °C for 24 h before being used as adsorbent for the experiment.

Nickel nitrate, $Ni(NO_3)_2.6H_2O$, was dissolved in distilled water to prepare the test solutions of approximately 20 mg/l Ni concentration. The exact concentration of Ni in the solutions was determined before each set of adsorption tests.

### Test for Agitation Time

250 ml Erlenmeyer flasks with 100 ml of adsorbate (Ni) solution were prepared. Initial concentrations of samples were measured. 500 mg of adsorbent (treated fibre) was measured and added to each of the conical flasks. The flasks were then agitated at 350 rpm using an orbital shaker. They were removed from the shaker for the determination of residual adsorbate concentration one after the other at 10, 20, 30, 40, 60, 80, 100 and 120 minutes. The samples were filtered and the final Ni concentrations were measured.

### Test for Optimum pH

250 ml Erlenmeyer flasks with 100 ml of Ni solution were used. The samples were adjusted to pH 4-9 by using 0.1 N sodium hydroxide (NaOH) or 0.1 N hydrochloric acid (HCl). 500 mg of treated was measured and added in each flask. The flasks were agitated at 350 rpm for the selected contact time. Then the samples were filtered and the final Ni concentrations were measured.

### Isotherm Generation

250 ml Erlenmeyer flasks with 100 ml of Ni solution were arranged. All samples were adjusted to the optimum pH. 100 to 1,000 mg (in increments of 100 mg) of treated fibre were measured and added to the samples. The conical flasks were agitated at 350 rpm for the selected contact time. The samples were filtered and the final Ni concentrations were measured.

### Analytical Techniques

Ni concentrations of the samples were measured using a Direct Reading Spectrophotometer (DR2010) after filtration with Whatman GF/C glass fibre filters. pH was measured with a pH-meter.

## RESULTS AND DISCUSSION

### Test for Agitation Time

Agitation or equilibrium time is an important parameter in the adsorption process. In this study, the agitation time was varied from 10-120 minutes in order to observe the amount of Ni adsorbed on 500 mg of treated fibre from 100 ml of aqueous nickel nitrate solution. The results are shown in the following figure (Figure 1).

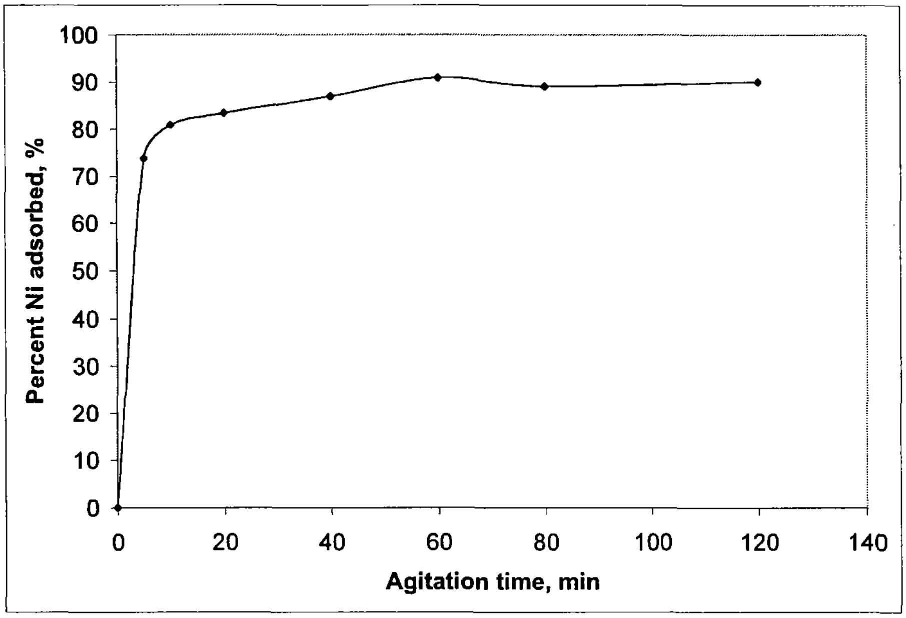


**Figure 1: Agitation time**

From Figure 1, it is noted that Ni adsorption was rapid during the first 20 minutes of agitation. Thereafter, the rate and amount of Ni adsorbed decreased. The processes were essentially complete after 90 minutes. Hence for the subsequent studies the agitation time was chosen as 90 minutes.

### Test for Optimum pH

pH is also an important parameter that affects the adsorption of metal ions. A set of experiments was conducted to determine the optimum pH for Ni removal. Various researchers have shown that different metals require different pH levels for their effective removal by adsorption using specific adsorbents. Kadirvelu and Namasivayam (2002) stated that the maximum removal of cadmium, Cd (II), using coconut coir pith was attained over the pH range 5-10. Selvaraj et al. (2003) found 93% removal of chromium, Cr (VI) by distillery sludge at pH 2-3 and that, when the pH was increased above 3 there was a reduction in adsorption. In another research, the maximum adsorption occurred at pH below 5 for chromium, Cr (VI), using rice husk activated carbon (Guo et al., 2002).

In this study, the pH was varied from 4-9 to determine the optimum value for Ni adsorption on treated fibre. The results are shown in Figure 2. Maximum Ni adsorption occurred at pH 7 and hence this was taken as the optimum pH for subsequent studies.

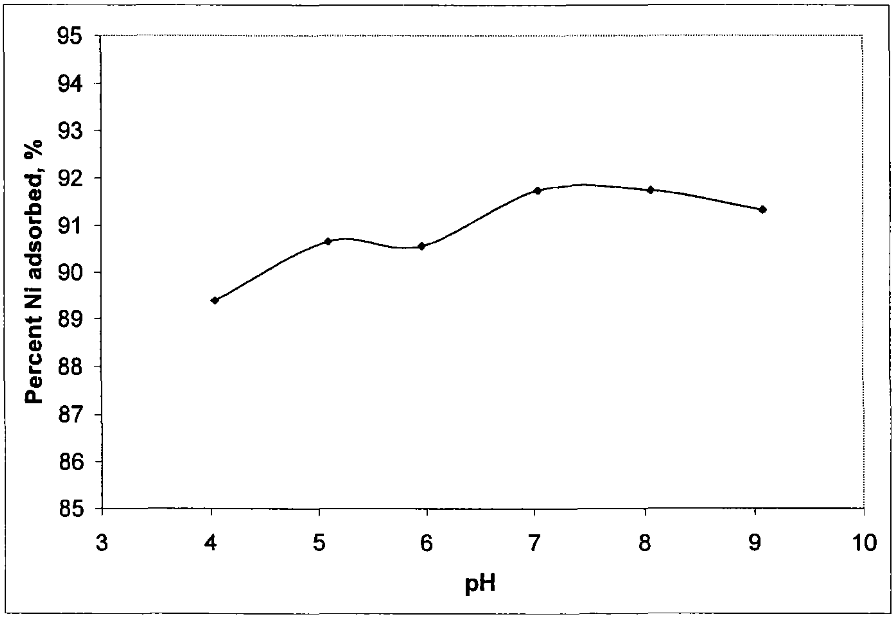


**Figure 2: Optimum pH**

## Isotherm Generation

Isotherms are mathematical equations used to describe the adsorption behaviour of any adsorbent-adsorbate combination. They model the adsorption behaviour and help in calculating the adsorption capacity of materials. Three commonly used adsorption equations are the Langmuir, Freundlich, and Brunauer-Emmett-Teller (BET) isotherms. The mathematical expressions representing these isotherms and their corresponding rearranged forms to obtain linear plots are as follow:

Langmuir equation,

$$\frac{x}{m} = \frac{abC}{1 + aC} \quad (1)$$

$$\frac{1}{(x/m)} = \frac{1}{abC} + \frac{1}{b} \quad (2)$$

Freundlich equation,

$$\frac{x}{m} = KC^{1/n} \quad (3)$$

$$\log\left(\frac{x}{m}\right) = \frac{1}{n}\log C + \log K \quad (4)$$

BET equation,

$$\frac{x}{m} = \frac{ACx_m}{(C_s - C)\left[1 + (A-1)\frac{C}{C_s}\right]} \qquad (5)$$

$$\frac{C}{(C_s - C)\frac{x}{m}} = \frac{1}{Ax_m} + \frac{A-1}{Ax_m}\left(\frac{C}{C_s}\right) \qquad (6)$$

where x = mass of material adsorbed (mg)
m = mass of adsorbent (mg)
C = concentration of adsorbate in solution after adsorption is complete (mg/l)
$C_s$ = saturation conc. of adsorbate (mg/l)
$x_m$ = amount of adsorbate adsorbed in forming a complete monolayer (mg/g)
a, b, K, n and A = constants

Figures 3, 4 and 5 show the Langmuir, Freundlich and BET plots respectively as obtained in this study. It can be seen from the plots that Ni adsorption by the treated fibre is best represented by the Freundlich isotherm (highest $R^2$ value).

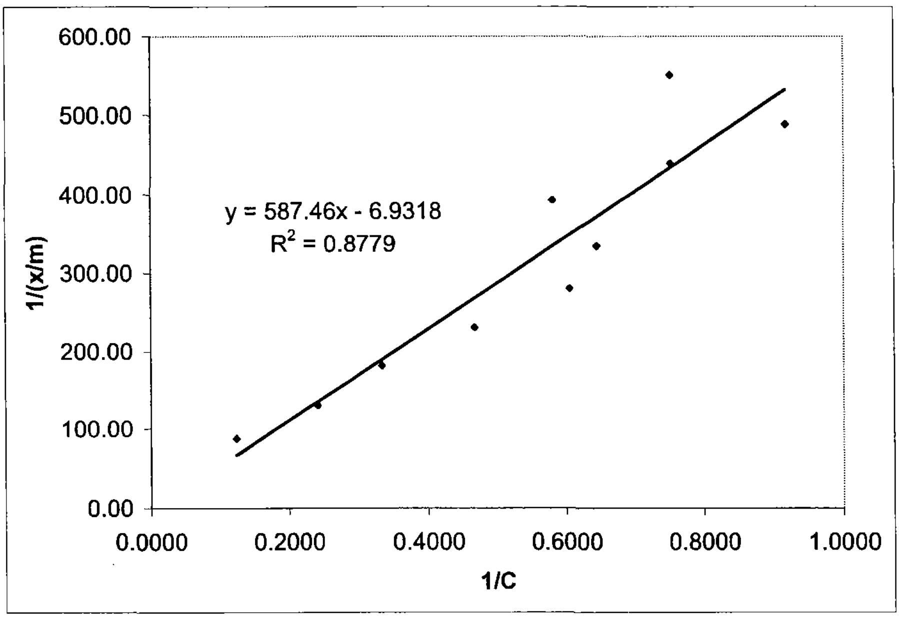


**Figure 3: Langmuir isotherm**

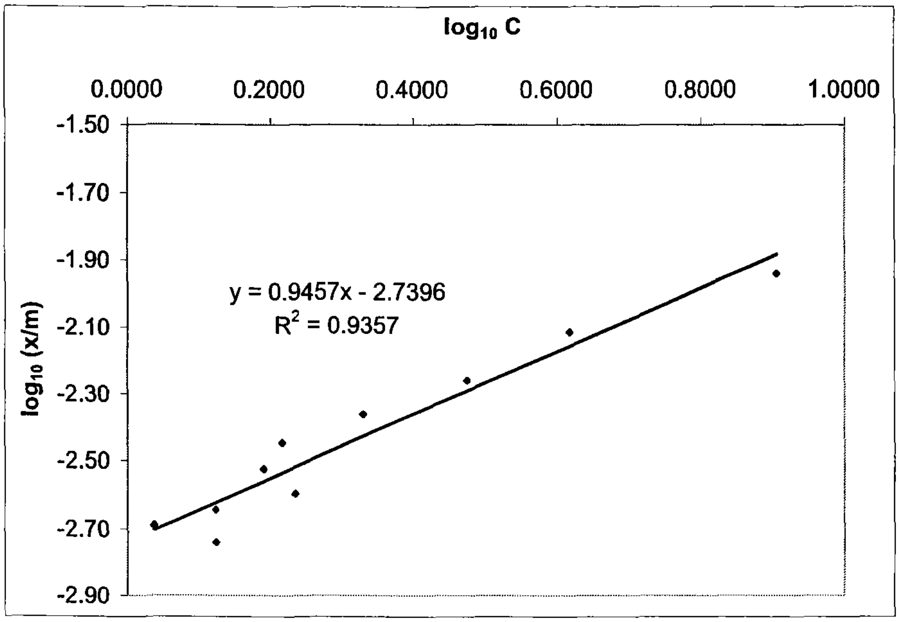


**Figure 4: Freundlich isotherm**

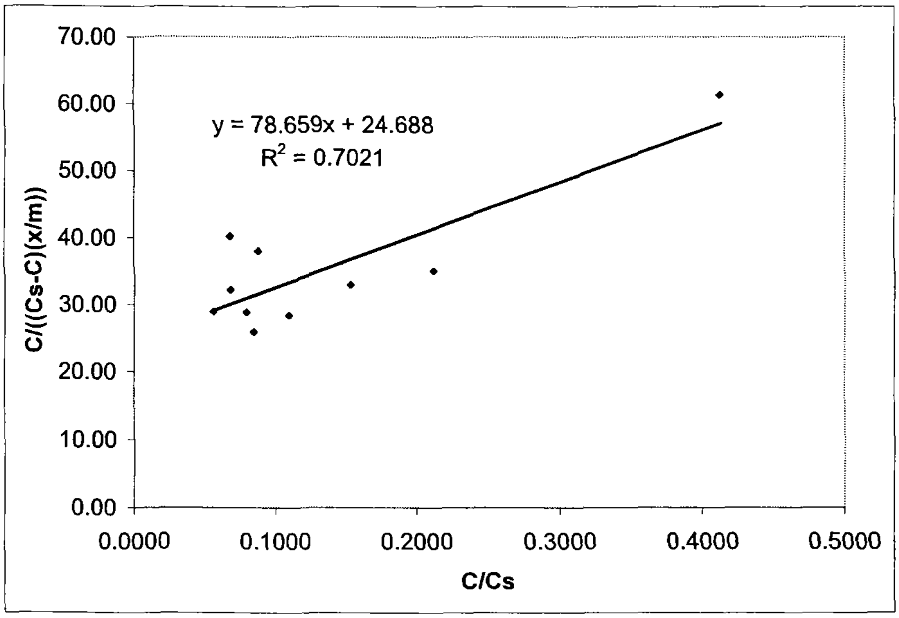


**Figure 5: Brunauer-Emmett-Teller (BET) isotherm**

Comparing the equation of the best fit line in Figure 4 with the Freundlich isotherm expression i.e. equation (4) above and solving for the constants yields:

K = 1.8214 _ $10^{-3}$ and n = 1.0574

Thus the Freundlich adsorption expression for Ni removal under the present test conditions is given by:-

$$\frac{x}{m} = 1.8214 ? 10^{-3} C^{0.9457}$$

## CONCLUSIONS

The following conclusions can be drawn from the present study:

- Treated fibre from palm oil industry is an effective adsorbent for Ni.
- Suitable agitation times for Ni adsorption are is 90 minutes.
- The optimum pH for Ni is 7.
- Ni adsorption is well described by the Freundlich isotherm.

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