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Potentiality of Palm Fibers As Bio Adsorbent for the Treatment of Ni (II) Ion Polluted Wastewater

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Abstract

Palm fibers (PF) was estimated for the discerning removal of nickel (Ni (II)) from wastewater. Laboratory experimental study was carried out to recognize the influence of pH and contact time on adsorption of nickel from an industrial wastewater. The adsorption procedure was obtained to be highest pH dependent, simplifying selective adsorption of metal verified. The height Ni (II) adsorption appeared at an initial concentration of 100 mg.L-1, 1 g doses of PF, and pH = 6. The efficiency of (PF) for nickel removal was approximately 68 % at these conditions. Equilibrium adsorption investigates at room temperature were carried out and matched to Langmuir and Freundlich models. The results revealed that nickel is significantly adsorbed on palm fiber (PF) and it could be cost-effective method for the removal of nickel from wastewater.

Keywords: palm fibers, wastewater, nickel, adsorption

1. Introduction

Pure water is the chief component of the earth and is necessary to the existence of all a live bodies. It is a resource of nutrition, healthiness and power. Several people in the world are realizing water emergencies remaining to the deficiency of perpetual rivers or lakes and very small rainwater, specifically in parched provinces such as the Saudi Arabia. Water is limited and is appropriate gradually additional valued in equivalent with the fast development of the worldwide population [1]. Furthermore, the augmented feeding of water in manufacturing, farming and houses has caused in the regular accumulation of billions of tons of wastewater to be freshwater resources. Agreeing to UN approximations, the whole almanac extent of generated wastewater is nearly 1500 km3, which is six intervals extra water than occurs in all the rivers of the world (UN WWAP 2003). Therefore, several fresh water tanks are suitable unsuitable for regular management outstanding to the crude removal of wastewater. Wastewater from productions, such as metallic coating, crush and paper construction, excavating processes, ceramics manufacture, and furnace production, manufacturing, composite construction, battery-operated engineering [2], fabric and pigments, is a main cause of the different types of dangerous wastes, which is growing in streak with quick developed development [3]. The amount of total contaminants in water, containing organic and inorganic toxins, is assumed to be above 700. Conversely, metallic contaminants are including the utmost hazardous due to their harmfulness and non-eco-friendly character. The extremely heavy metal have damaging results on the environmental equilibrium and the extended period consequences of which influence not be yet identified. For example nickel, mercury, and copper etc. and are widely accessible in the appearance of oxides or sulfides or as a salt of iron, calcium, copper etc. [4]. Persons may meeting heavy metal by biological methods, manufacturing basis, or from unplanned suppliers. Drinking water may become polluted by usage of insecticides, geographical metal residues or unsuitable discarding of metals substances [5]. Nickel salts are generally consumed in metal electroplating and its amounts in manufacturing wastewaters variety from 3.40 to 900 mg L-1. Highest acceptable control for nickel in bottled water has been rigid as 50 mg L-1 by European Commercial Group [6]. The chronic harmfulness of nickel to humans and the ecosystem is well recognized and extreme nickel concentration produces lungs and bone cancers. Toward explain this difficulty, much exertions has been created to generate an economically and industrially desirable replacement to additional the activated carbon as nickel adsorbent [7]. The conventional reason of heavy metals elimination is to delicacy metal polluted

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wastewater. The extra heavy metals are exclusion by many physical and chemical methods such as chemical precipitation[8], ion exchange [9] biosorption, adsorption [10], membrane filtration[11], coagulation and flocculation [12], electrochemical behaviors etc. [13]. In latest years, some agriculture wastes were discovered as adsorbents in the handling of wastewater [14]. An optimum adsorbent for the elimination of organic and inorganic compounds in wastewater should have the following properties: low price, affluence of supplying, ecological objectivity, high attraction and high capability. In this background, some plants adsorbents like Sugarcane bagasse were intended by Rao and Ibrahim [15-16], potato peels[17], rice husk [18] as a new adsorbent for the deletion of nickel ions from solutions. Shukla et al., [19] reviewed adsorption of Nickel exhausting Maple sawdust, the nickel removing capacity of a biosorbent Pine bark [20]. Consequently, the present paper investigated the adsorption capacity of palm fibers on nickel ions removal from the waste- water. The palm fibers are the fibers cellulosic containing frequently of polysaccharides. These mean to a extensive variation of polymers, primarily named carbohydrates, the principal ones, concurring to their richness in nature, cellulose, hemicellulose, lignin etc. [21]. Palm fibers has illustrated specific notice as efficient biosorbent owed to its little charge competed with activated carbon and its great substances of hydroxyl functional groups, the carbon content and surface area illustrating extreme adsorption ability for removal of contaminant in wastewater [22]. The purpose of the current study is to investigate the probability of using the palm fibers for removing nickel ions. The results of adsorbent concentration, pH, contact time and initial metal ion concentration on the adsorption capability were examined. Adsorption isotherm models and thermodynamic parameters were also investigated. This research was performed in College of Science and Arts, Jouf University.

2. Materials and Methods

2.1 Preparation of the adsorbent

The palm fronds were collected to obtain the palm fiber (PF) from palm plantations in the Kingdom of Saudi Arabia. The (PF) was washed very well several times with distilled water, then then dried at 100 °C for 4 h and sieved. The four adsorption investigations were carried out at room temperature of 25°C (± 2).

2.2 Preparation of adsorbate

Nickel (II) solutions were prepared in the laboratory depending on metal concentration in the industrial effluent by diluting 1000 ppm of Ni $(NO_3)_2\cdot 6H_2O$ (Merck) stock solution with distilled water to a desired concentration which ranged between 10 and 200 mg/L. Before mixing the adsorbent, the pH of each test solution was adjusted to the required value with diluted and concentrated HCl and NaOH solutions, individually. The concentration of remaining Ni (II) was detected spectrophotometrically after adsorption. The absorbance of the solution was study at 340 nm.

2.3 Adsorbent characterizations

The chemical characterization of the PF was established according to Ramadevi et al. [23] were estimated the cellulose, hemicellulose and lignin content gravimetrically [24]. The hemicellulose content was analyzed by deducting the hollocelulose from the cellulose content [25]. The functional groups were identified using Fourier transformed infrared, FT-IR spectroscopy (4200-FTIR JASCO, Japan).

2.4 Adsorption Studies

Batch adsorption investigations were carried out at room temperature by shaking 0.5 g of the palm fibers (PF) with 100 ml of nickel (II) solutions of known concentrations and known pH using an orbital shaker of 250 rpm. The influence of pH was considered by regulating the pH of the solutions using 1 N HCl or 1 N NaOH solution. pH was determined with a pH meter. The influence of initial metal ion concentrations was conducted by stirring 100 ml nickel (II) solutions of desired concentrations (10, 20, 30, 40, 50, 60, 70, 80, 90 and 100 mg/L) with 0.5 g of the adsorbent. Finally the samples were regulated to the optimal pH before adding the adsorbent. The samples were reserved from the shaker at pre-determined time periods and nickel (II) solution was removed from the adsorbent by centrifugation at 4000 rpm for 6 min. All the examinations were conducted in repeat to prevent any inconsistency in investigational calculations and metal solution regulators were preserved during the experiment to preserve superiority control. The measurement of metal adsorbed was calculated by the equation (1) [26]:

$$Adsorption\ (\%) = \frac{Ci - Ce}{Ci} \times 100 \qquad (1)$$

Where, *Ci* and *Ce* are the initial and equilibrium concentration of metal ion (mg /L) in the solution. Adsorption capacity was calculated by consuming the mass residue for the adsorbent as shown in equation (2) [26]:

$$q = \frac{(Ci - Ce)V}{W} \qquad (2)$$

Where, q is the adsorption capacity (mg /g), V is the volume of metal ion solution (L) and W is the mass of the adsorbent (g).

The chemical characterization of the palm fibers cellulose, hemicellulose and lignin are presented in Table 1. These analyses show that the palm fibers have the higher content in cellulose (56.73%) and a lesser content in lignin (17.93%).

Table 1. Chemical composition of palm fibers (PF)

Constituent	Weight (%)

Cellulose	66.31
Hemicellulose	14.27
Lignin	12.05
Extractives	1.45
Ashes	1.46
Other	4.46

3. Results and Discussions

3.1 Adsorbent characterizations

The chemical characterization of the palm fibers (PF) established on the major constituents namely cellulose, hemicellulose, Lignin, extractives, Ashes and many other low molecular weight compounds as shown in table (1). According to these findings, palm fibers have the highest cellulose percentage (66.31%) and the lowest lignin content (12.05 %). FT-IR is used to determine the chemical functional groups in a substance as chemical bonds have different energy adsorption bands and can provide a rapid and qualitative suggestion around the variation in the chemical construction [27]. In FT-IR spectra of PF the adsorption bands varying from 3450 to 3200 cm^{-1} characterizes –OH stretching vibrations of cellulose, hemicellulose and lignin [28]. The peaks at 2930 cm^{-1} and 2845 cm^{-1} are in conventionality with C-H groups. The exclusive peak at 1621 cm^{-1} obeys C=O stretching from ester groups or carboxylic groups. The peak at 1264 cm^{-1} and 1035 cm^{-1} which signifies the stretching vibration of C-O. These chemical groups viewed in PF could aid to entice and confiscate Ni (II) onto the biosorbent. By relating the FT-IR spectra of PF before and after adsorption by IR correspondence there were extraordinary changes in some possess. These changes may be credited to the variations in counter ions related with carboxylate and hydroxylate anions, signifying that acidic groups, carboxyl and hydroxyl, are major providers in metal ion uptake. Furthermore, reduces in strength of heights were examined in all the PF loaded with Ni (II) IR spectrum [29].

3.2 Effect of contact time on the adsorption of Ni (II) onto PF

Fig. 1 represents the influence of contact time on the degree of adsorption of Ni (II). It has been examined that adsorption amount raised from 15% to 68% with increasing on contact time from 5 to 180 min. Highest Ni (II) removal was attained within 60 min after which Ni (II) concentration in the test solution became constant. It may be justified by the point that primarily for adsorption great number of empty sets existed, which reduced later due to tiredness of residual surface sets and repulsive force between solute molecule and bulkiness phase [30]. It is extremely apparent that after the vacant surface locations unavailable, the metal ions were unrestricted with sustained, protracted vibration. The connection between adrsorbent and adsorbate ions may be physical in character with no chemical connecting as the fibers can be respected raw with no obtainable negatively charged functional groups to potentially trick the metal ions [31].

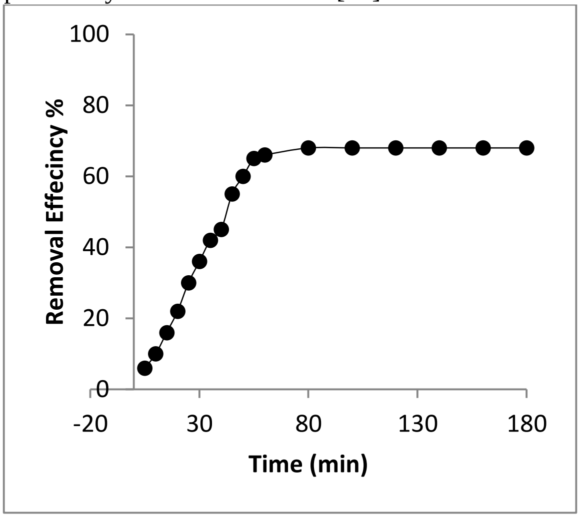

Figure 1. Effect of contact time on the biosorption of Ni (II) by PF at initial metal ions concentration of 100 $mg.L^{-1}$.

3.3 Effects of initial metal ion concentration on the adsorption of Ni (II) onto PF

Figure 2 demonstrate that the adsorption capability increased with increasing metal ion concentration from 10 to 100 ppm. The higher initial metal concentration increases the attraction of metal ions towards active sets. On the other hand, the adsorption ability continued almost constant from 80 to 100 ppm signifying that the active sets are completely employed [32].

3.4 Effects of initial pH on the adsorption of Ni (II) onto PF

Metal adsorption is significantly connected with pH. In order to determine the influence of pH on the adsorption of Ni (II) onto adsorbent, the batch adsorption analysis at changed pH values were carried out in the range of 2.0-12.0. No reports were done beyond pH 6.0 because of the precipitation of the Ni (II) as its hydroxide (Fig. 3). From results, it is that maximum adsorption of Ni (II) was 71.8 % at pH 6.0. pH of the solution shows a very significant function in the metal uptake. Both adsorbent surface metal binding sets as well as metal chemistry in solution are induced by pH of the solution. At low pH values, metal cations and protons contest for forcing sets on adsorbent surface which results in lower uptake of metal. It has been recommended that at highly acidic condition, adsorbent surface ligands would be closely associated with H_3O^+ that limits entrance to ligands by metal ions as a effect of repulsive forces. It is to be predictable that with increase in pH values, more and more ligands having negative charge would be showed which result in increase in attraction of positively charged metal ions

[33]. In addition at higher pH the lower binding is attributed to reduced solubility of the metal and its precipitation [34].

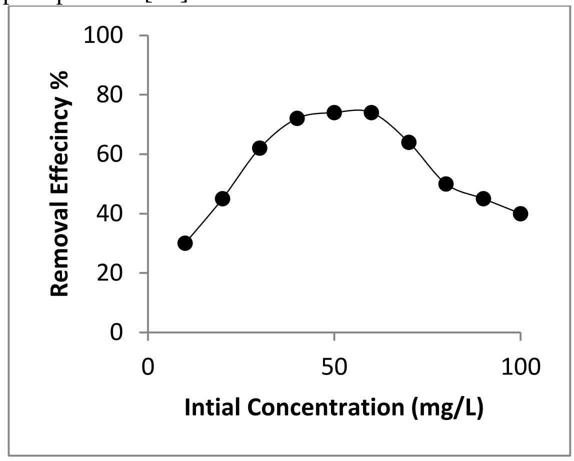

Figure 2. Effect of initial ion concentration on the biosorption of Ni (II) by PF at 60 min

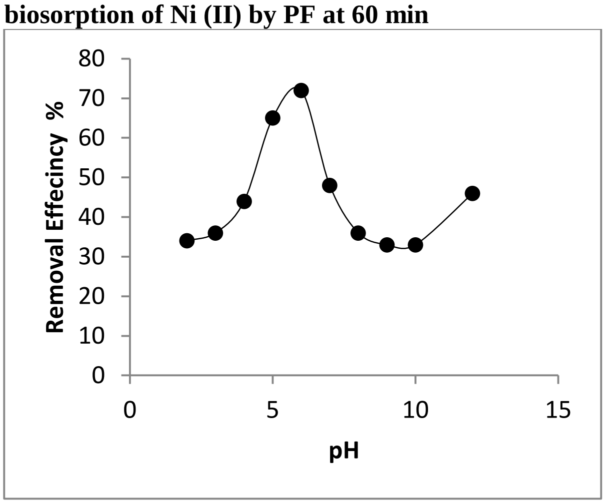

Figure 3. Effect of pH value on the biosorption of Ni (II) by PF at initial metal ions concentration of 100 mg.L^{-1} and 60 min.

3.5 Effect of adsorbent dose on the adsorption of Ni (II) onto PF

The mass of the adsorbent has large influence on the adsorption procedure. Influence of biosorbents dose on percentage removal of Ni (II) was examined by changeable adsorbents dose in the range of 0.1 g L^{-1} to 5.0 g L^{-1}. It was noted that the percentage removal of Ni (II) increases with the increase in the adsorbent dose (Fig. 4). The maximum proportion removal of Ni (II) was 68 % at 1.0 g L^{-1} of biosorbents dose and constant initial metal ion concentration of 100 mg L^{-1}. The fact of increase in percentage removal of Ni (II) with increase in adsorbent dose may be justified as with increase in adsorbent dose, more and more surface becomes obtainable for metal ion to adsorb and this increase the rate of adsorption [35-37].

3.6 Adsorption isotherms

Biosorption isotherms explain in what way adsorbate interrelates with biosorbent and equilibrium is determined between adsorbed metal ion on the biosorbent and the remaining metal ion in the solution during the surface biosorption. Equilibrium isotherms are calculated to establish the capacity of the biosorbent for metal ion. The equilibrium records was investigated by two parameter isotherms: Langmuir and Freundlich. The Langmuir example is stated by the linearized eqn. (3) [38]:

$$1/qe = 1/qmax + 1/(b\,Ce \times qmax) \qquad (3)$$

Where q_{max} is the maximum amount of metal sorbed (mg·g^{-1}), b is a constant associated to the energy of sorption. The Freundlich typical is characterized by the linearized equation as follows [39]:

$$\ln(qe) = \ln(Kf) + 1/n \ln(Ce) \qquad (4)$$

Where K_f is the biosorption equilibrium constant, demonstrative of the sorption ability, and n is a constant investigative of biosorption strength. It has been proposed that n is the heterogeneity factor. The predictable adsorption parameters by the various examples Langmuir, Freundlich isotherms are shown in Table 2. The 1/n values are between 0 and 1 (n>1), demonstrating that the adsorption of Ni (II) onto PF is a physical process [38] and the values of correlation coefficient (R_2) are considered as a degree of the good -of- well of experimental data on the isotherm's models. The applicability of the two isotherm's models for the present data approximately follows the order: Freundlich > Langmuir (Table 2). The adsorption calculations attained are greatest explained by the Freundlich isotherm model. It can be observed the obtained values are within the range of other materials that have been previously reported in literature as: Maple sawdust [19], Zea maize leaves [40], raw corn stalk [11], Luffa cylindrical [20], Coconut shell [13], Sugarcane bagasse [15], Pine bark [41], Maize bran [42] and Teak tree bark powder [43]. The adsorption by PF is attained to be higher than most of the other agricultural adsorbents. It shows that PF is a strong for the efficient removal of Ni (II) from aqueous solutions through biosorption.

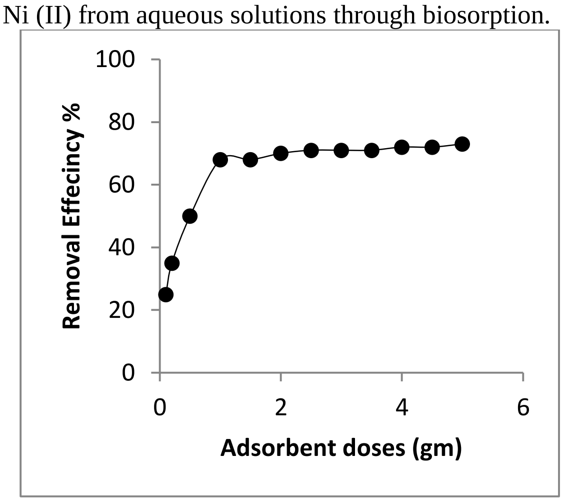

Figure 4. Effect of adsorbent doses on the biosorption of Ni (II) by PF at initial metal ions concentration of 100 mg.L^{-1} and 60 min

Table 2. Parameter of Langmuir and Freundlich equation for biosorption of Ni (II) ion on (PF)

Parameter	Ni (II)	
Freundlich constants	K_f	6.048
	1/n	0.230
	R^2	0.994
Langmuir constants	q_{max}	3.820
	K_L	0.194
	R^2	0.948

4. Conclusion

Palm fibers (PF) biomass was chosen for examining biosorption due to the opportunity of exploiting a waste biomass to remove the metal contamination. It is seen fr om the results that at 1.0 g/100mL of PF could remove about 68 % at 60 min contact time of nickel. Optimal pH of adsorption was discovered to be 6. Equilibrium adsorption showed that system followed both Langmuir and Freundlich model. The result of this study will facilitate in suggesting the biosorbers exhausted in the industry for elimination of Ni (II) ions from their wastes. Furthermore, the use of palm fibers waste will reduce the usage of activated carbons, which are frequently attained from wood, thus protecting our environment. In the view of these results, it can be concluded that the PF can be utilized as a low cost and effective adsorbent in removal of Ni (II) ions from aqueous solutions.

Conflicts of Interest

The authors declare no conflict of interest.

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