



Removal of Copper(II) and Nickel (II) from Aqueous solution by adsorption on Sugarcane Bagasse

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Abstract

In this study, the capacity of untreated and treated Sugarcane Bagasse by hydrochloric acid or caustic soda on the elimination of heavy metal Copper and Nickel from aqueous solution was investigated. The experimental work was carried out at room temperature and the influence of pH, contact time and Bagasse mass was determined. By increasing the contact time, the Bagasse mass and the pH of the solution, the amount of each metal adsorbed increases considerably. The results showed that Sugarcane Bagasse was found better treated by alkaline than chloride solutions with a good efficiency to remove Cu (II) > Ni(II).

Keywords: Adsorption, copper ion, nickel ion, sugarcane bagasse, maximum adsorption capacity.

Introduction

Many heavy metals used in various industrial and agricultural activities can be found in waste waters in soluble or insoluble form. Their presence is toxic for human health and all watery species depending on their concentrations and bioaccumulation conditions. Nowadays, the elimination of different form of heavy metal from aqueous solutions is very important and is increasing tremendously. Diverse technical treatments as chemical and electrochemical precipitation, solvent extraction, adsorption and ion exchange, have been developed and applied to reduce the concentration of heavy metals ions from contaminated water before their rejection in the natural environment¹⁻³.

Adsorption is an effective technology largely used for the elimination of heavy metals from aqueous solutions. The commercial activated carbon is the adsorbent one more used because it has good adsorbent properties, but it is relatively expensive. For a few years, many investigations have been proposed on the utilization of low cost material as substitutes or complement to commercial activated carbon. These work showed that the chemical treatment of the natural adsorbents improve their adsorbent properties^{4,5}.

Various materials, including agricultural materials as bark, sawdust, green and red alga, have been studied for this purpose^{6,7}.

This study considers the adsorption of copper and nickel metal ions which are frequently encountered in industrial wastewater on the Sugarcane Bagasse.

Different parameters were examined such as temperature, contact time and Sugarcane Bagasse mass.

Adsorption is a process which leads to the equilibrium distribution of metal between the adsorbent and the solution. The determination of the quantity of metal adsorbed is based on the interpretation of the adsorption isotherms which translate the relation between the concentration of metal in solution and its adsorbed quantity. For the determination of maximum adsorption capacity, the Langmuir equation was applied in this study^{8,9}.

Material and Methods

Sugarcane Bagasse was provided by Saris Congo, Sugar Industries Corporation (Nkayi).

The adsorbent was crushed and sifted to obtain the particles of dimensions lower than 100 μm , then washed with distilled water and the adsorbent was then dried at 70°C during 6 hours in a dryer¹⁰. The figure-1 shows the Sugarcane Bagasse used as adsorbent for this study.

Aqueous solutions of metals were prepared with reagents $\text{Cu}(\text{NO}_3)_2 \cdot 3\text{H}_2\text{O}$ for the cupric ion, and $\text{NiCl}_2 \cdot 6\text{H}_2\text{O}$ for nickel ion. To obtain solution with the desired initial concentration of 6,5 mg/L for each ion to be used for adsorption experiments, this solution was diluted with distilled water.

The experiment was carried out in a 100 ml beaker with 50 mL of each metal solution, mixed with a given amount of adsorbent and the mixture was shaken in a magnetic stirrer for a desired time and pH. The variation of different parameter studied were 2 to 20 g/L for the mass of Sugarcane Bagasse, 0,5 to 5 hours for the shaking time and 1.2 to 6.5 for the pH ; the limit value of pH was chosen to avoid the chemical precipitation of metal hydroxides¹¹. The diluted solution of hydrochloric acid or

caustic soda of concentration 0,1 M was used to adjust the pH of solution at the desired value before its measurement by pH-meter HANNA instruments HI 83141 with combined glass electrode¹².



Figure-1

The adsorbent using for the removal of Cu(II) and Ni(II)

At the end of each stirring time, the metal solution and adsorbent were separated by filtration using Whatman filter papers and the surviving solution was analyzed by UV-Visible photometer Aqualytic AL 800 to determine the equilibrium concentration after adsorption C_e . The determination of equilibrium concentration of each metal was carried out using a calibration curve established at the wavelength corresponding to the maximum of absorption of each metal ion. It means 800 nm for nickel ion and 825 nm for cupric ion. The Blank solutions were constituted by distilled water with adsorbent.

The treatment of adsorbent by hydrochloric acid or caustic soda was consisted to mix and be shaken 50 g of adsorbent with one liter of HCl 0.1 M or one liter of NaOH 0.1 M during 12 hours and the adsorbent was washed with distilled water on the Whatman filter papers under the pH of filtered water become neutral¹³. The wet adsorbent was again dried at 70°C during 6 hours.

The equation-1 was used to determine the amount of each adsorbed metal when the equilibrium is reached¹⁴

$$q_e = \frac{(C_o - C_e) V}{m} \quad (1)$$

In this equation,, q_e is the amount of metal adsorbed per unity of adsorbent mass (mg /g); C_o and C_e are respectively the initial and equilibrium concentration of metal (mg/L), m is the mass of adsorbent (g), V is the volume of metal solution in the beaker

(L).

The removal metal percentage was determined by the equation-2¹⁵

$$\%Ads = \frac{(C_o - C_e) 100}{C_o} \quad (2)$$

The maximum adsorption capacity of each metal was determined by using the linear form of Langmuir isotherm¹⁶ given by the equation - 3.

$$\frac{1}{q_e} = \frac{1}{q_{max}} + \frac{1}{q_{max} C_e b} \quad (3)$$

In this equation q_{max} is the maximum adsorption capacity (mg/g) and b the Langmuir constant (L/mg).

The intercept and the slope of the plot of $1/q_e$ versus $1/C_e$ were used to determine respectively the maximum adsorption capacity q_{max} and the equilibrium constant b .

Results and Discussion

Effect of pH on the metal adsorption: Many research tasks on the adsorption of metal ion from aqueous solution showed that the pH of the solution has a great influence on the percentage of metal adsorbed.

The figure-2 shows the percentage of each metal adsorbed as function of the pH for a mass of untreated Bagasse of 10 g/L and a time of contact of two hours. From this figure, the percentage of each metal adsorbed increases with the pH. This results shows the basic character of the adsorption site of adsorbent as indicated by Olayinka¹².

The effect of this parameter was explained by another authors such relied by the existence of area charge on the adsorbent; Naveen¹⁸ indicated that surface area of adsorbents is sensitive to pH of solution and plays an important role in adsorption of ions from aqueous solutions.

Ghomri⁵ explains the low percentage of adsorption at low value of pH by a competition between the hydronium ions and the metal ions on adsorption site available on the adsorbent area. The figure-2 shows that the maximum adsorption of each metal ion occurs at pH range between 5 and 6.

Effect of contact time on the metal adsorption: The study of influence of contact time on the adsorption of copper and nickel ions on the Sugarcane Bagasse was carried out at pH 5 with a Bagasse mass of 20 g/L while varying this parameter from 0,5 to 5 hours. The results obtained are presented in figure-3.

Figure-3 indicates that the percentage of each metal adsorbed from the aqueous solution increases quickly with stirring time and decreases after three hours.

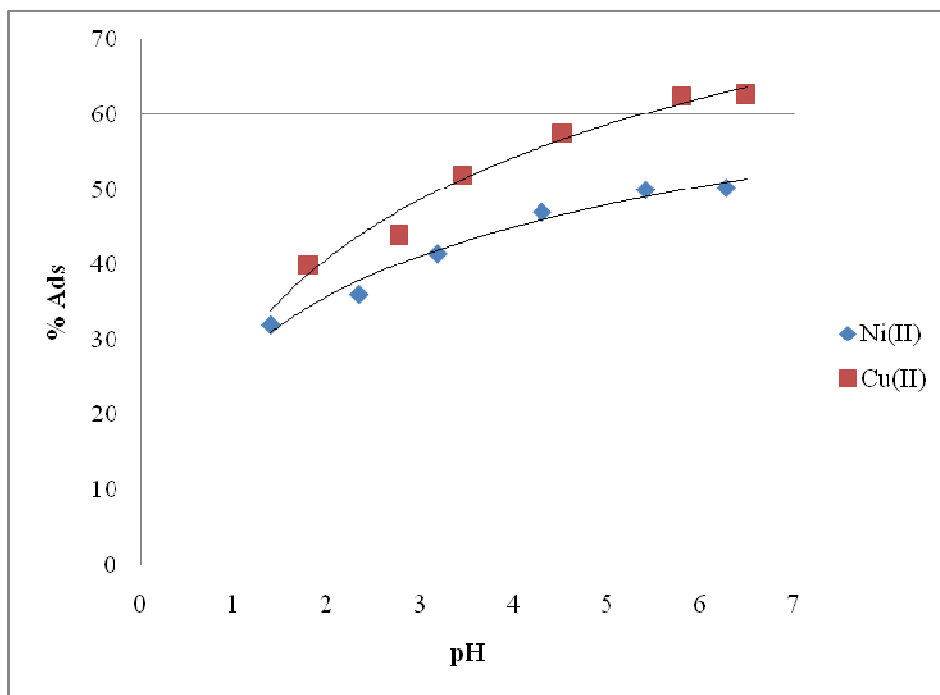


Figure-2
 Effect of pH on removal of Cu(II) and Ni(II)

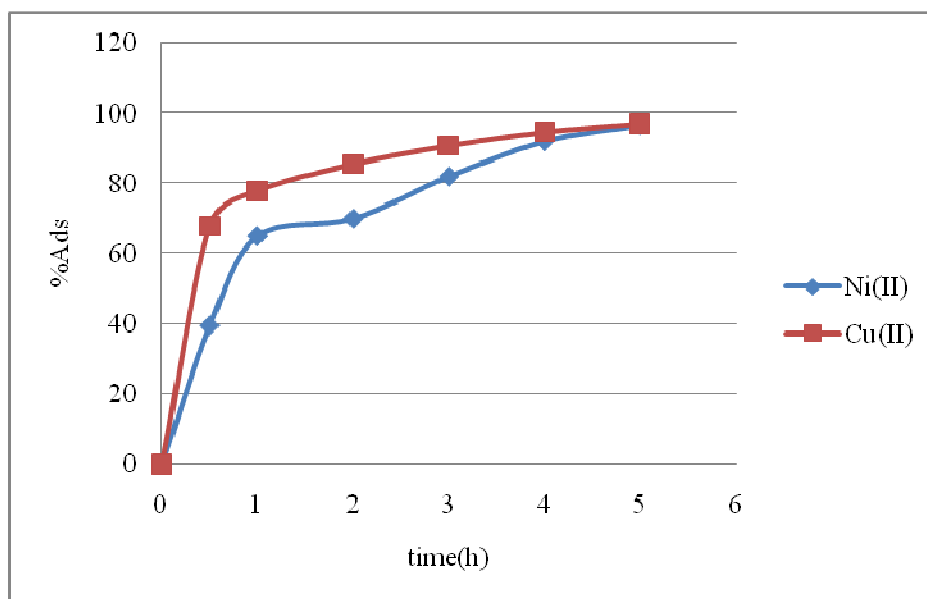


Figure-3
 Effect of contact time on removal of Cu(II) and Ni(II)

It is observed that the efficiency of metal ion adsorption is related with the increase of contact time. The maximum adsorption is noticed at contact time of 3 hours for copper and 3,5 hours for nickel.

According to Nassima studies¹⁹, the decreasing of the percentage of metal adsorbed after three hours is probably due

to the resistance of transfer of matter inside the particle of adsorbent.

To explain this phenomenon, Malarvizhi⁹ indicated that during the initial stage of adsorption, a large number of vacant surface sites are available for adsorption, whereas after a long time, the remaining vacant surface area sites are difficult to occupy due to

repulsive forces between the adsorbate on the solid surface area.

Effect of the mass of Bagasse on the adsorption: In the study of influence of this parameter on the percentage of adsorption of each metal ion, the mass of Bagasse varied from 2 to 20 g/L, the pH of the solution being maintained to 5 with a contact time of two hours. The figure-4 shows the results obtained.

As this figure shows, the percentage of adsorption of each metal increases with that of the mass of Bagasse. With a Bagasse mass of 10 g/L, the percentage of removal metal was 77.5% for nickel ion and 89.95% for cupric ion. This increase of percentage of adsorption can be explained by the presence of high number of adsorption sites on the area of adsorbent.

Determination of the maximum adsorption capacity: The determination of the equilibrium concentration of metal ion made it possible to determine the adsorption capacity for each

value of mass of Bagasse using the Equation-1. The maximum adsorption capacity q_{max} was determined by exploitation of Langmuir isotherm starting the plot $1/q_e$ versus $1/C_e$.

The figures-5 and 6 show the corresponding curve for Cu(II) and Ni(II). The values of maximum adsorption capacity q_{max} of untreated Sugarcane Bagasse at 25°C was 7.88 mg/g for nickel and 14.31 mg/g for copper.

The table -1 shows related values of q_{max} and b for each metal obtained with untreated and treated Bagasse. This result confirms that the Bagasse adsorbs better copper than nickel.

The comparison of the maximum adsorption capacities indicates that the adsorption of these metal ions is done in the order $Cu > Ni$. The high values of R^2 confirm that the Langmuir isotherm can be applied to describe the adsorption of Cu(II) and Ni(II) from aqueous solution on Sugarcane Bagasse.

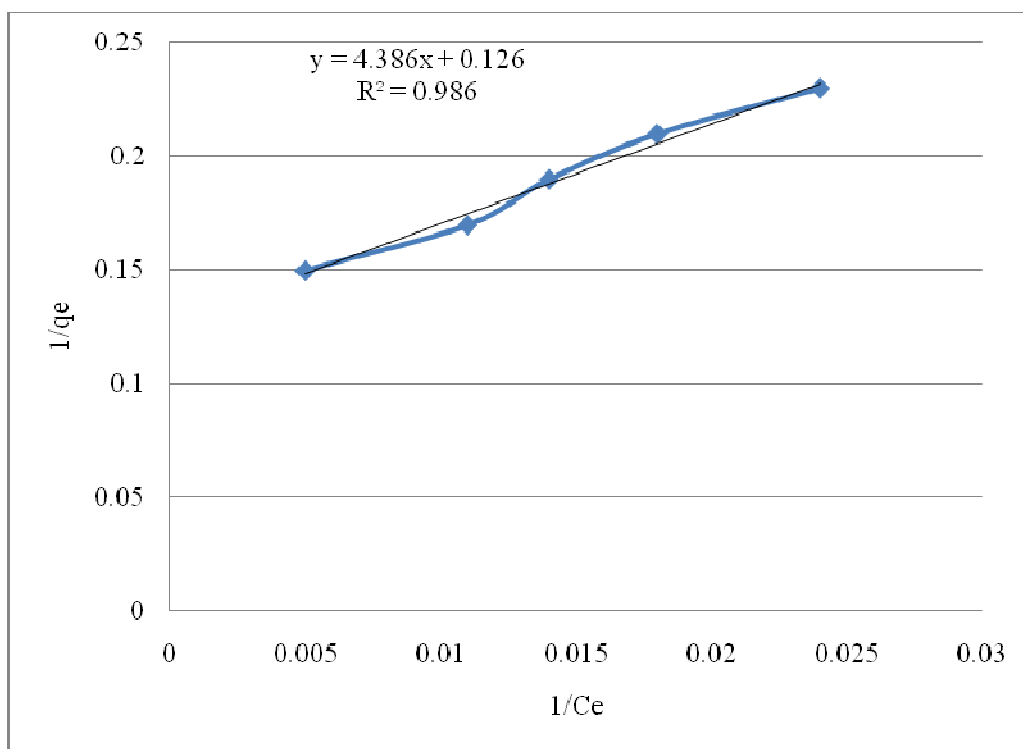


Figure-4
 Effect of Bagasse mass on removal of Cu(II) and Ni(II)

Table-1
 Langmuir parameters of Ni(II) and Cu(II) on untreated and treated Sugar Bagasse

Langmuir parameters	Untreated bagasse		Bagasse treated by HCl		Bagasse treated by NaOH	
	Ni(II)	Cu(II)	Ni(II)	Cu(II)	Ni(II)	Cu(II)
q_{max} (mg/g)	7,88	14,31	11,3	16,98	12,76	24,57
R^2	0,98	0,97	0,95	0,94	0,95	0,96

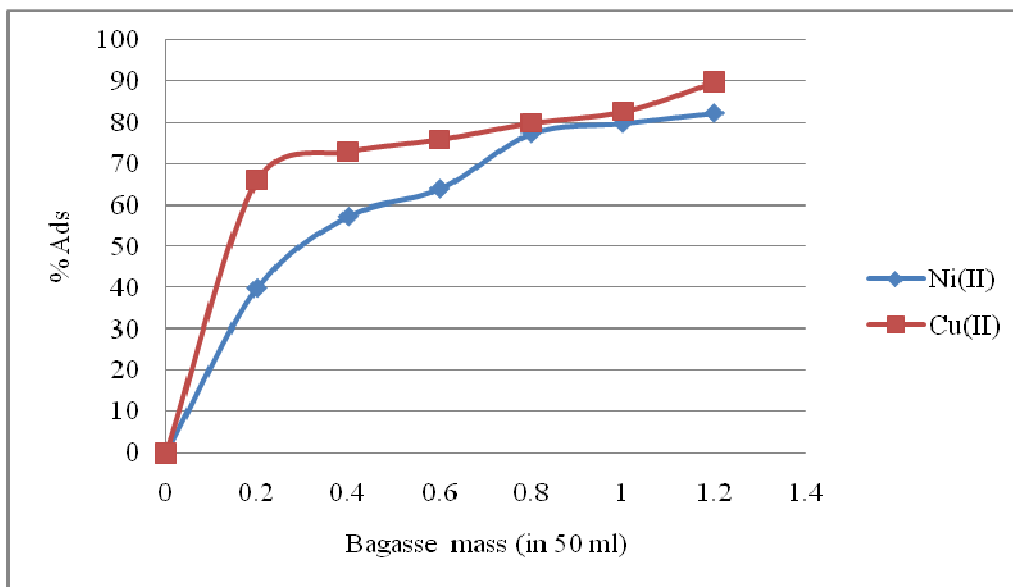


Figure-5
 The Langmuir isotherm for Ni(II) adsorption

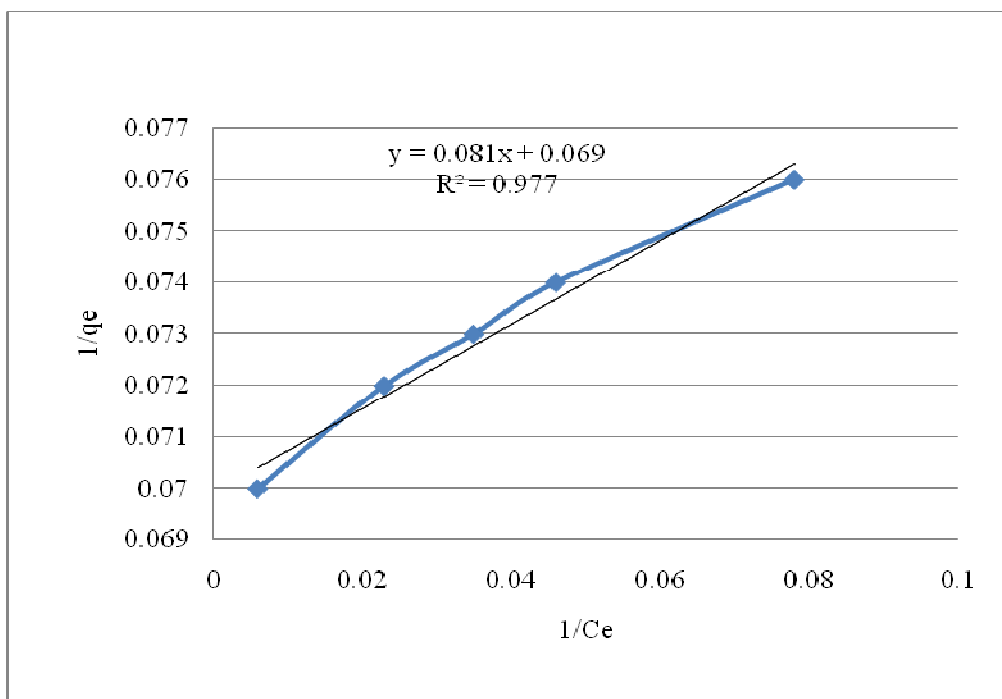


Figure-6
 The Langmuir isotherm for Cu(II) adsorption

Conclusion

The objective of this work was to study the influence of pH, contact time and mass of adsorbent on the adsorption of Cu(II) and Ni(II) from aqueous solution on the Sugarcane Bagasse. By increasing pH, Bagasse mass and stirring time, the amount of metal adsorbed slightly raised. The optimum condition for each

metal was around pH 5, three hours for contact time and 10 g/L for Bagasse mass. The application of the model of Langmuir isotherm gave a maximum adsorption capacity of 7,88 mg/g for Ni(II), and 14,31 mg/g for Cu(II) onto untreated Bagasse, which indicates that Bagasse adsorbs more Cu(II) than Ni(II) under the same experimental conditions. The treatment of Bagasse by HCl 0.1 M or NaOH 0.1 M before adsorption

experiment increased the amount of adsorbed metal.

This agricultural material, available in high quantities in the locality of NKAYI (Republic of CONGO) can serve as alternative of commercial adsorbent in elimination of heavy metals in waste waters before their rejection in the natural environment to limit the pollution phenomena.

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