Liquid - solid extraction of Co^{2+} ions from aqueous solutions diluted by the sugarcane bagasse

S. Elanza*, H.Taouil, A. Lebkiri, E.H. Rifi.

Abstract — The present work concerns the liquid-solid extraction of metal ions Co^{2+} from aqueous solutions diluted by the sugarcane bagasse (SCB). The kinetic study at T = 25 ° C, and at pH = 5.5 shows that the extraction equilibrium is reached at 35 min. The extraction yield is all the more important as the pH imposed on the solution is high. The maximum binding capacity of Co^{2+} by SCB is of the order of 2.88 mg/g. Under the operating conditions used, a mass of 0.8 g of the SCB is sufficient to completely purify at 20 ppm of cobalt solution. The study of the regeneration of this material, after deextraction of the metal ions by bringing it into contact with dilute acid solution shows that this material has good mechanical properties and can be regenerated and repeatedly reused in the process of treating the metal solutions.

Keywords — Liquid - solid extraction, Cobalt, sugarcane bagasse, extraction kinetic, deextraction, regeneration.

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1 INTRODUCTION

The contamination of water by toxic metals causes a major environmental and health problem. To remedy this problem, many physicochemical methods have been developed for the removal of toxic metals from aqueous solutions such as: The liquid-liquid extraction [1- 4], the liquid-gel extraction [5-12], the membrane separation [13-16], the exchange of ions [17-20], precipitation, flotation. These methods have several disadvantages like high operating costs, low selectivity, incomplete removal, and production of large quantities of wastes.

In recent years several research projects have focused on the use of solid - liquid extraction for the following advantages: Simplicity of equipment, more economical, Use of natural materials of low cost and not toxic, regeneration of the solid phase by a simple washing. [21-29].

In this work, we have studied the extraction of Co^{2+} ions from aqueous solutions diluted by sugarcane bagasse. We studied the extraction kinetics, the effect of different physicochemical parameters on the extraction of Co^{2+} ions (pHi, mass of material, initial concentration of Co^{2+} ions, temperature). Also, the deextraction and regeneration of material.

2 Materials and methods

2.1 Choice of material and metal

In this work, we have chosen the sugarcane bagasse as extractant matrix for the following reasons:

- Its high content of cellulose, hemicellulose and lignin, which are contained in their structures of the groupings hydroxyls and phenol hydroxides, which play an important role at the level of extraction mechanisms of heavy metals.
- Another essential reason, it is that the sugarcane bagasse is available and less expensive.
- We chose the cobalt as metal to extract from aqueous solutions, because of its massive use in several industrial fields [30-31]. It is also, the cobalt is known to be one of the heavy metals most toxic to living organisms and it is one of the more widespread heavy metal contaminants of the environment.

2.2 Preparation of metal solutions and material

The metal solutions of cobalt are prepared by dissolving of the cobalt chloride salt hydrated ($CoCl_2$, $3H_2O$) in distilled water. The pH of each solution was adjusted by hydrochloric acid (HCl) and the sodium hydroxide (NaOH).

The sugarcane bagasse is the residue which remains after the extraction of sugar contained in sugarecane; it was dried with the air, under the action of the solar rays, then crushed and tamised so as to obtain homogeneous materials for the experimental achievements, and the fraction of granularity of very low diameter

2.3 method of analysis

The dosage of metal solutions of Co^{2+} ions is realized at Laboratory of the National Office of Hydrocarbons and Mines

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(ONHYM), by the technique of the Inductive Coupled Plasma-Atomic Emission Spectrometry (ICP AES). The spectrometer used is of type JY-38.

2.4 The yield and the extraction capacity

The evaluation of the effectiveness of extraction is carried out either by determining the extraction yield, denoted R%, or by calculating the extraction capacity, denoted q, expressed in mg of metal per g of extractant support. The extraction yield R% is calculated using the following formula:

$R\% = (Co - Ce)\ 100/Co$

The extraction capacity at time t is defined by the following formula: $qe\ (mg/g) = (Co - Ce)\ V/m$

Co: initial concentration of metal (ppm).

Ce: residual concentration of metal at the equilibrium extraction (ppm).

V: volume of the metallic solution (l).

m: mass of the support extractant introduced in solution (g).

3 Results and discussions

3.1 Effect of contact time

The effect of time on the extraction of metal ions by the SCB was studied by taking 0.5 g of SCB with 100 ml of metal solutions of 20 ppm.

The simultaneous evolution of the binding capacity of the Co^{2+} ions (q) and the pH of the aqueous solution as a function of the contact time of the aqueous phase with the solid phase are shown in the Fig 1. The kinetics of extraction of Co^{2+} by sugarcane bagasse shows an increase in the quantity of metal fixed on the SCB with increasing time. The yield and maximum capacity (q_m) values at equilibrium after 35 min are estimated to be 64.5% and 2.58 mg /g respectively. This increase in extraction performance is accompanied by a decrease in the pH value of the metal solution from the first minutes of contact between the liquid phase and the solid phase, followed by a steady state. The decrease in pH shows that the material equilibrates with the metal solution by releasing H^+ protons from hydroxyl sites, hydroxides of phenols to the aqueous solution, and consumes the metal ions Co^{2+}.

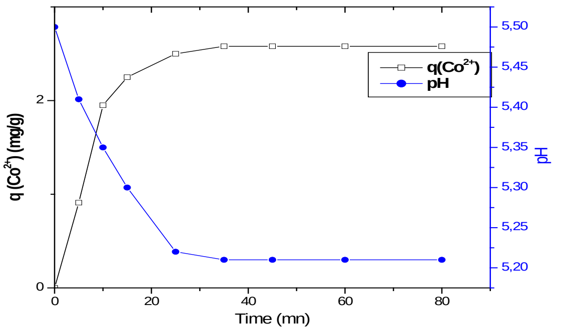

Fig 1: kinetics of extraction of Co^{2+} by the sugarcane bagasse.
Vaq = 100 ml, $[Co^{2+}]$ =20 ppm, pHi = 5.5, m (SCB) = 0.5 g, T = 25 °C

3.2 Effect of t initial pH on extraction

The pH of solution has been identified as the most important variable governing metal uptake on (SCB).

In fig 2, we have observed the evolution of the binding capacity of cobalt on the SCB as function of time for different values of the initial pH. We note that the kinetic curves of Co^{2+} obtained have the same allure and that the higher the initial pH of each solution, the more the maximum quantity of the metal bound to the solid phase increases. Also, the time required to reach the extraction equilibrium increases as a function of the pH. For a pH = 4, the extraction equilibrium is reached at 15 min of agitation of the system, and the maximum binding capacity of the Co^{2+} ions is of 2.04 mg/g, on the other hand for a pH = 7, the equilibrium becomes slow and is obtained only after 60 min. The maximum extraction capacity of Co^{2+} increases to 2.78 mg / g.

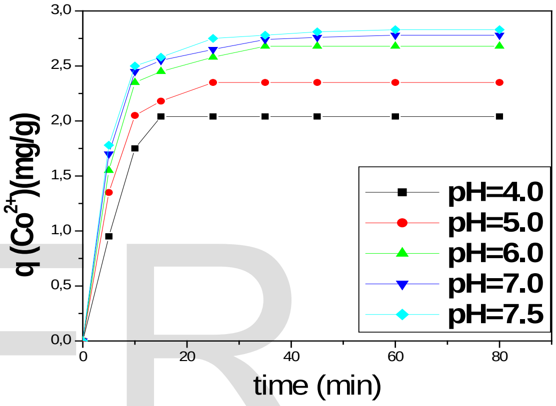

Fig. 2: Effect of initial pH on the extraction kinetic of Co^{2+} by SCB

3-3 Effect of the initial concentration of Co^{2+} ions

The application of the process of extraction of cobalt by the sugarcane bagasse on synthetic solutions at different concentrations (20, 40, 50, 100, 150, 200, 250, 300, 400 ppm) enabled to determine the maximum quantity extracted at the equilibrium.

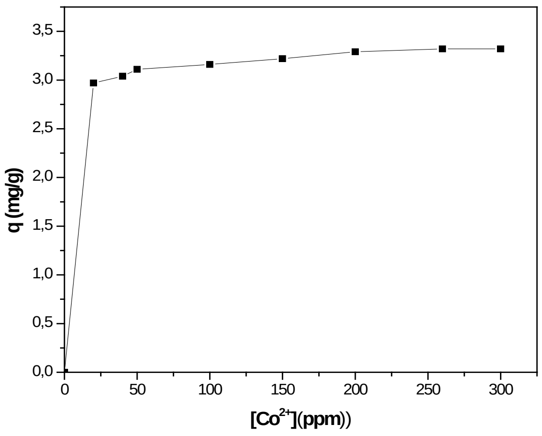

Fig 3: Effect of $[Co^{2+}]_i$ on the binding capacity on the SCB

The presented curve in figure 3, shows an increase in the fixing capacity with the concentration of cobalt and ends with a saturation starting from 250 mg/g, where the quantity of cobalt removed by sugarcane bagasse becomes constant (qm = 3.32 mg/g). This result enables to conclude that this value represents the maximum quantity of cobalt that can be fixed on one gram of the sugarcane bagasse in our operating conditions.

3.4 Effect of the material mass

The effect of the SCB dose on the removal of metal ions is shown in Fig 4. Adsorption increased from 57.0 to 72.0%.

The effect of material mass quantity was studied by varying the quantity of material in the range of 0.2–1.6 g whereas the parameters such as initial dye concentration, contact time, pH of the solution, stirring rate and temperature were all kept constant during the adsorption process.

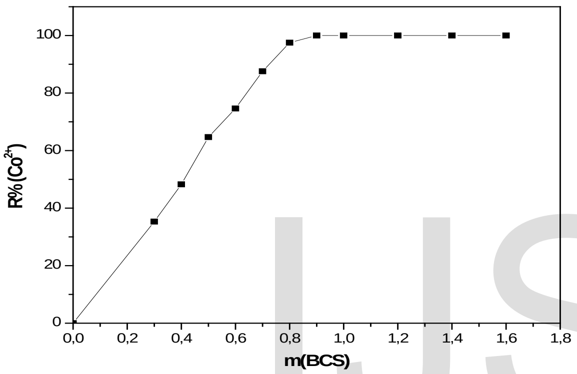

Fig 4: Effect of the mass of SCB on the extraction of Co^{2+}
Vaq = 100 ml, pH = 5.5, [Co2+] = 20 ppm, T = 25 0C

3-5 Effect of temperature on the extraction of Co^{2+} by SCB

The results of the effect of temperature on the extraction capacity of Co^{2+} ions by sugarcane bagasse are shown in Fig 5

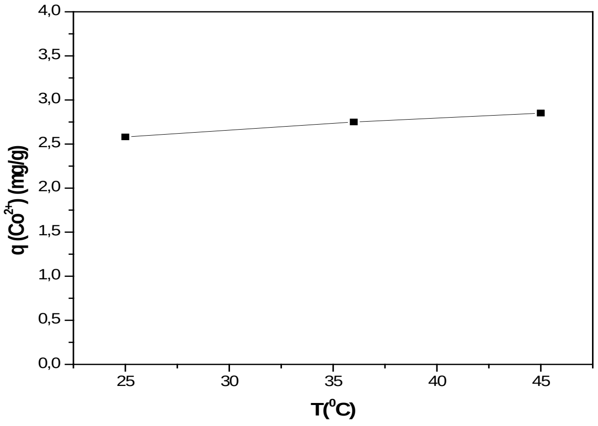

Fig.5: Effect of the temperature on the extraction capacity of Co^{2+} by the SCB.
Vaq = 100 ml, $[Co^{2+}]$ = 20 ppm, m (SCB) = 0.5 g, pH = 5.5.

The results of this curve clearly show the notable effect of the temperature on the capacity of extraction of Co^{2+} by the SCB. Indeed, the binding capacity of Co^{2+} on the SCB increases from 2.58 to 2.85 mg / g when the temperature increases from 25 ° C to 45 °C.

Therefore, it can be concluded that the temperature promotes the retention of the Co^{2+} ions on the SCB, which results in an endothermic process.

Table 1: Capacities and yields of Co^{2+} ions for different temperature values

T (⁰C)	25	36	45
R%	64	68	71
q(mg/g)	2.58	2.75	2.85

3.6 Deextraction and regeneration

3.6.1Effect of the concentration of mineral acid on deextraction

In this part, we have prepared of dilute solutions of the hydrochloric acid (HCl) of different concentrations (0.1 mol / l, 0.15 mol / l, 0.2 mol / l). In 100 ml of each solution, a bag of filter paper containing the SCB loaded with cobalt. Les supports utilisés de la BCS contenant les masses du Cobalt suivantes : 0.98 mg, 1.175 mg, 1.235 mg. La masse de chaque support extractant utilisé est de 0.5g.

The curve of variation of the concentration of the cobalt in the acid solutions as a function of time is shown in fig 6.

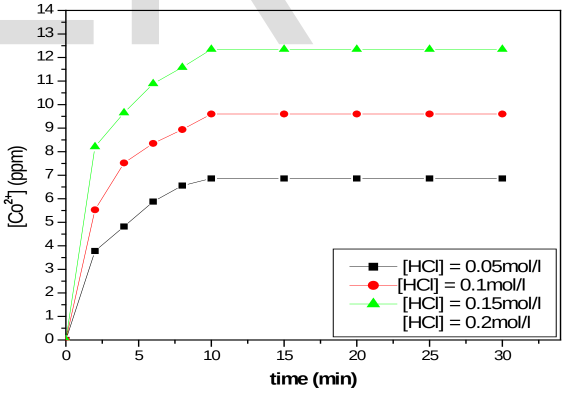

Fig 6: Deextraction of cobalt fixed on the SCB as a function of the time for different concentrations of HCl

These results show that the release of the Co^{2+} ions fixed on the SCB depends on the concentration of the acid solution and that the more the concentration of the mineral acid increases the more the liberation of the metal ions fixed on the material increases. For a concentration of 0.1 mol/l of the acid solution, we have about 60% of Co^{2+} was recovered, and for a concentration of 0.15 mol/l we have 86% Co^{2+} was recovered, and the SCB is completely emptied of metal for a concentration 0.2 mol/l of HCl.

Also, the kinetics of deextraction of metal ions on the acid solutions is very fast, and we have about ten minutes of agitation of systems to achieve the equilibrium.

3.6.2 Effet de cycles de réutilisation du matériau sur le rendement d'extraction

To carry out this study, we used a solution of HCl of concentration 0.2mol/l as a deextraction agent because the latter offers a better metallic recovery. Three consecutive cycles of extraction / deextraction are carried out for the SCB loaded with Co^{2+}.

The table 1 summarizes the variation of extraction yields of Co^{2+} by the SCB respectively as a function of the reuse cycles.

Table 2: Extraction yields of Co^{2+} by the SCB as a function of the reuse cycles.

Number of cycle	1	2	3
R% (Co^{2+})	100	99.8	99.75

According to the results of this table, the extraction yields of Co^{2+} by SCB are almost identical in the three repeated cycles. Therefore, it can be concluded that the SCB material has good mechanical properties and can be regenerated and repeatedly reused in the process of treating the metal solutions.

5 Conclusion

The liquid- solid extraction of Co^{2+} ions from aqueous solutions diluted by the sugarcane bagasse was studied. The kinetic study shows that the yield and maximum capacity (q_m) values at equilibrium after 35 min are estimated to be 64.5% and 2.58 mg /g respectively. The effect of the concentration of Co^{2+} and the initial pH on the extraction shows that the binding capacity increases with increase in the pH_i and the concentration of metal ions. Under the operating conditions used, a mass of 0.8 g of the SCB is sufficient to completely purify at 20 ppm of cobalt solution. The study of the effect of the temperature on the extraction, shows that the temperature favors the retention of metal ions on the support used which results in an endothermic process.

The study of the regeneration of this material, after deextraction of the metal ions by bringing it into contact with dilute acid solution shows that this material has good mechanical properties and can be regenerated and repeatedly reused in the process of treating the metal solutions.

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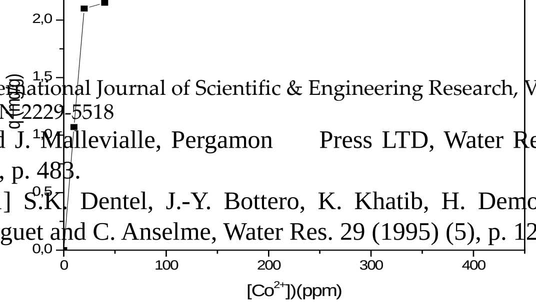

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