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APPLICATION OF MAIZE TASSEL FOR THE REMOVAL OF Cu(II) FROM SYNTHETIC WASTEWATER

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Abstract

Copper is a widely used metal which is also an essential micronutrient for human life. This metal, however, can be toxic to humans in high concentrations. The mining of copper has resulted in the contamination of water bodies by this metal. This poses a health threat to human lives and, therefore, calls for its removal and ultimately its recovery from water bodies. This study was aimed at the recovery of copper from synthetic industrial wastewater using maize tassel, an agricultural waste material. Batch experiments were conducted to look at the impact of various parameters such as pH and contact time on the ability of tassel to remove Cu^{2+} from aqueous solution. The results obtained so far showed that the recovery of copper by tassel is pH dependent. The percentage removal of Cu^{2+} from a 20 ppm solution ranged from 29.5-33.9 % at pH 1. However, at pH 4 higher percentage recovery range of 56.7-73.2 % was achieved. Furthermore, it was also noted that the equilibrium was achieved within a period of 30 min. The recovery of Cu^{2+} from aqueous solutions by using cheap and readily available waste material offers a good alternative to the currently used expensive methods.

INTRODUCTION

The importance of water can never be over emphasized. Water contamination, water shortages and misuse of water are the major challenges facing the water sector. The treatment of contaminated water emanating from industries is one of the major focus areas. It is a requirement of the National Water Act of South Africa; Act 36 of 1998; Chapter 3 part 4; section 19 subsection 1, that “an owner of land, a person in control of land or a person who occupies or uses land on which (a) any activity or process is or was performed or undertaken; or (b) any other situation exists which causes, has caused or is likely to cause pollution of a water resource must take all reasonable measures to prevent any such pollution from occurring, continuing or recurring”. The burden is placed on industry to treat wastewater before discharging into water bodies.

Heavy metals have been identified as a common source of environmental pollution. The high affinity of heavy metals for soil organic matter has resulted in their accumulation in soils (3; 17). The most disturbing fact about heavy metals and their speciation products is that they tend to end up in water sources where they accumulate by either physical and / or by biological processes in the food chain of aquatic organisms (18). Copper (Cu) bearing mine waste contributes significant quantities of dissolved copper into wastewater (8). Copper is an essential micronutrient for human life, but it is however detrimental in large quantities (7; 8). The allowable quantities of Copper in water as stipulated by the Environmental Protection Agency is 1,3 mg/l. Copper enters the blood and muscle, liver and brain once it is absorbed into the gastrointestinal tract. High levels of copper can cause stomach intestinal distress, kidney damage, anemia and even death (6; 12; 17; 8). This metal has been implicated in several water pollution problems in South Africa's water resources due to its use in many industries, such as metal plating, mining operations, and tanneries (2; 7; 15; 12; 17). This calls for its removal and ultimately its recovery from water bodies. Its recovery could contribute to the South African economy since copper is an important coin metal.

A lot of research has been focused on the removal of heavy metals from water and wastewater due to their well known toxicity (2; 19). Thus far, the technologies that have been developed for the removal of heavy metals from aqueous solutions include ion exchange, reverse osmosis, membrane filtration, sludge leaching, electro winning, solvent stripping, precipitation and adsorption (2; 6; 10; 16; 20). From the above mentioned processes, adsorption is the predominantly used method with commercial activated carbon as the most successful adsorbent (9). This method is however, quite expensive. Therefore, this raises the need for less expensive treatment methods.

Agricultural waste materials such as palm kernel husk, modified cellulosic material, corn cobs, residual lignin, wool, apple residues, olive mill products, polymerized orange skin, banana husk, pine back, sawdust, and others, have been reported for the removal of toxic metals from aqueous solutions (2; 4). The application of agricultural materials in wastewater treatment has also been reported (1; 11; 4; 13). However, most of these agricultural materials investigated so far have limitations in terms of efficiency and their adsorption capacities for heavy metals.

Maize tassel is the male inflorescence of the maize plant that forms at the top of the stem. It is discarded by local communities in South Africa and elsewhere in large quantities with the rest of the plant once the cobs have been harvested. Being plant material, it is postulated that tassel contains cellulosic surface hydroxyl groups that can bind positively charged metal ions. This means that tassel surface is a high energy surface. This has been confirmed by the ability of tassel powder to remove heavy metals from aqueous solution from our earlier studies (19; 20; 21).The aim of this study was to use maize tassel powder to remove copper from laboratory synthesized water.

MATERIALS AND METHODS

Instrumentation

A labcon oven model: FSOM4 Laboratory Marketing Services cc, P.O. Box 155 maraisburg 1700, South Africa was used to dry the maize tassel after washing and to dry glassware. A labcon shaking water bath, manufactured by: Laboratory Marketing Services cc, P.O. Box 155 maraisburg 1700, South Africa, was used for agitating the tassel-water mixture. A metrohm 713 pH meter, made by metrohm Herisau Switerland was used to measure pH adjustments. A varian 220FS Flame Atomic Absorption spectrometer(FAAS) coupled to an SPS5 (sample preparation system) and a sample introduction pump system (SIPS) was used for analysis of copper concentrations. A hammer mill model: Laboratory Mill 3 100 Stockholm, Sweden was used to grind tassel petals into powder.

Reagents

All chemicals used were of analytical reagent grade. Millipore deionised water (18.2 MΩcm) was used for preparing working standards and diluting samples. Blue, hydrated copper sulphate crystals (Merck), were used to prepare the stock copper solution.

Maize tassel powder preparation

The maize tassel petals were obtained by plucking from the mainly woody maize plants from Tshwane University of Technology farm in Pretoria South Africa. The material was first air dried for 7 days and then thoroughly rinsed with copious amounts of deionised water. The material was then placed in an air powered drying hood to remove dripping water. Finally the tassel was dried in an oven with the temperature set at 105 ^{o}C for 24 h to expel any moisture present. The dried material was then milled by a hammer mill model Laboratory Mill 3 100 Stockholm, Sweden. Thereafter, the milled tassel was sieved to a particle size of 500 μm sieve.

Methods

Batch experiments were conducted for the adsorption of copper using tassel powder. A known amount of adsorbent was equilibrated with 100 ml of a known concentration of copper in 250 ml volumetric flasks. After removal from the water bath, the samples were filtered through a 125 mm filter paper (Machery Nagel 640 we ashless). FAAS was used to determine the un-adsorbed copper in solution.

RESULTS AND DISCUSION

Effect of contact time

An initial copper concentration of 20 mg/l was used. The pH was adjusted to 4.5. The temperature of the water bath was set at 25 ^{0}C and the shaking speed was set at 150 rhythms per minute (rpm). 1 gram (g) of tassel powder was added to a 250 ml volumetric flask containing 100 ml copper solution. In the first 20 minutes a sample was removed after every 5 minutes (mins) from the water bath. As one can see from Fig.1, most of the adsorption took place within 30 mins, after which equilibrium was reached.

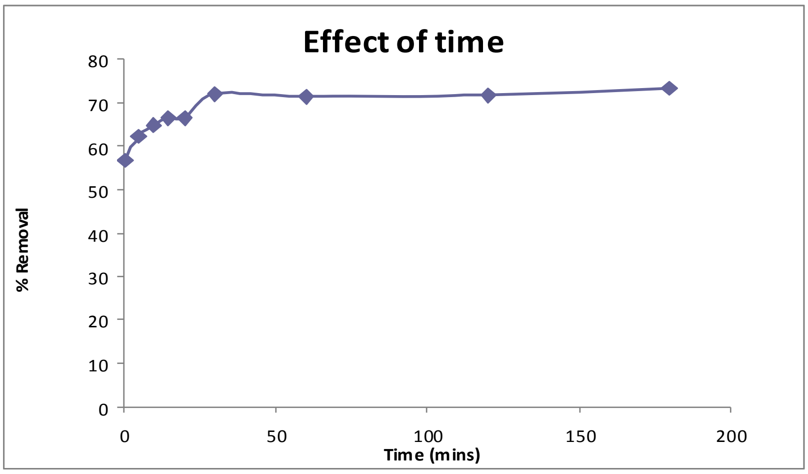

Figure 1: effect of contact time on the adsorption of Cu(II) with tassel powder

Effect of pH

The same conditions as those used for the effect of contact time were applied, except that the samples were equilibrated for 1 hour (hr) at pH 1, pH 4, pH 6 and pH 7. Minimum adsorption took place at pH 1 (Fig.2), because at this pH the adsorbent tends to be more acidic and thus contains only a few metal binding groups on its surface. As the pH was increased to 4, a 79% removal was achieved. A further increase in pH caused the removal percentage to decrease because copper precipitates at around pH 7 and above. These results coincide with what has been published in literature (17).

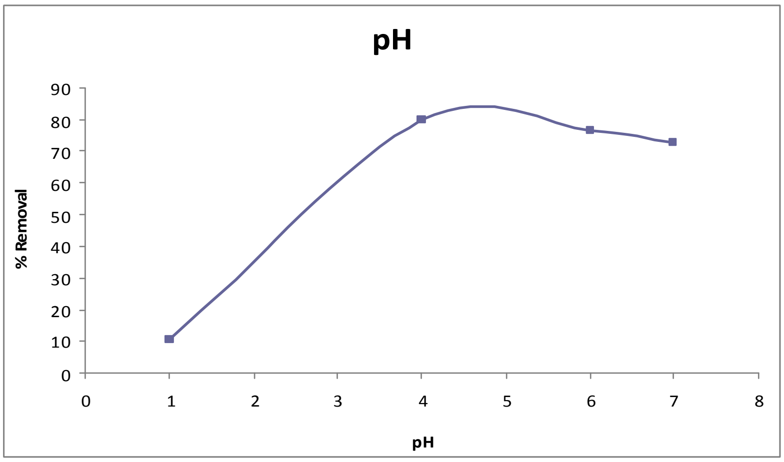

Figure 2: effect of pH on the adsorption of Cu(II) with tassel powder

Effect of temperature

An initial copper concentration of 20 mg/l was used and its pH was adjusted to 4.5. 1 gram (g) of tassel powder was used. The shaking speed of the water bath was set at 150 rhythms per minute (rpm). The samples were equilibrated at varying temperatures of 20, 25, 30, 40 and 50. Temperature seems to have no significant effect on the adsorption of copper ions onto maize tassel powder.

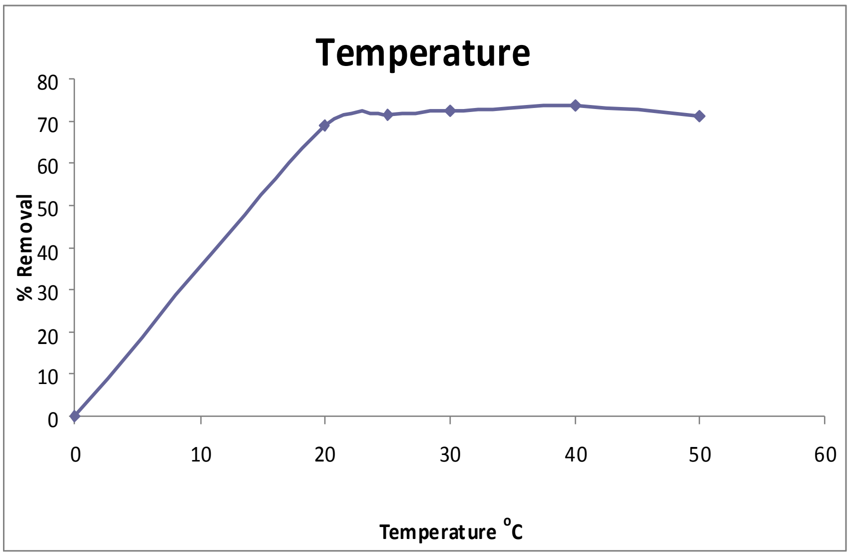

Figure 3: effect of temperature on the adsorption of Cu(II) with tassel powder

Effect of equilibration speed

An initial copper concentration of 20 mg/l was used. The pH was adjusted to 4.5. 1 gram (g) of tassel powder was used. The temperature of the water bath was set at 25 ^{0}C. The shaking speed of the water bath was initially set at 20 rpm, the samples were allowed to shake for an hour. Another batch of samples was equilibrated at 40 rpm for 1 hour. The rest of the batches which followed were equilibrated at 60 rpm, 80 rpm, 100 rpm, 150 rpm, 200 rpm and 250 rpm. The increase in shaking speed, like temperature, had no significant impact on the adsorption process.

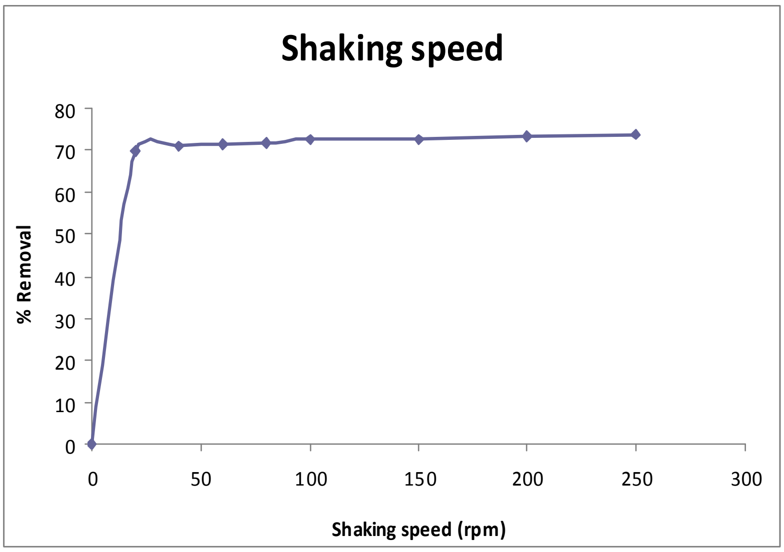

Figure 4: effect of shaking speed on the adsorption of Cu(II) with tassel powder

Effect of concentration

Different concentrations of copper ion solutions of 20 mg/l, 40 mg/l, 60 mg/l, 80mg/l and 100 mg/l were used. 1 gram (g) of tassel powder was used. The shaking speed of the water bath was set at 150 (rpm). The pH of the samples was adjusted to 2, 4, 6, 7 and 8. The samples were allowed to shake for an hr. The results followed the trend of the results obtained for the effect of pH. The increase in concentration does not affect the capacity of the tassel up to 80mg/l. The capacity of the tassel begins to decrease at a concentration of 100mg/l, meaning that the exchange sites of tassel begin to fill up as the concentration increase.

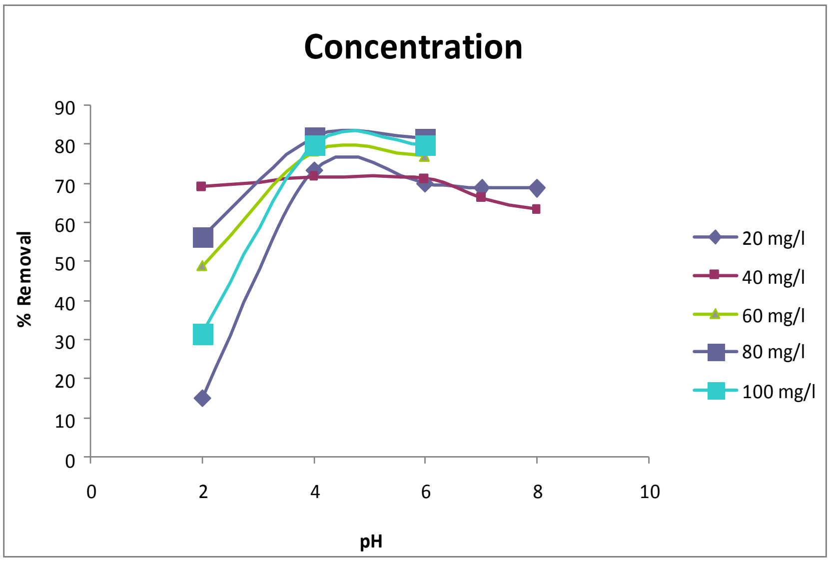

Figure 5: effect of concentration on the adsorption of Cu(II) with tassel powder

Effect of adsorbent dose and particle size

The effect of particle size was studied in conjunction with adsorbent dose. Different grams of tassel (0.2, 05, 1.0, 2.0 and 5.0) were used. Different particle sizes of tassel (0-500 µm; 500≤300µm; 300≤150 µm; 150≤50 µm and 50≤0 µm) were used. All the above experiments were carried out with particles ranging from 0-500 µm. It was observed with the naked eye that the sample dosed with 5 g tassel powder became too saturated with the powder and thus providing little space in the reaction flask for adsorption to take place, it is also evident from Fig.6 that the percentage removal begins to decrease when a high adsorbent dose is used. It can also be observed from Fig. 6 that maximum percentage removal of 80% was achieved with an adsorbent dose of 0.2 g with particle sizes ranging between 50 µm and 150 µm. This is a great advantage because a minimum amount of adsorbent is required per 100 ml of wastewater.

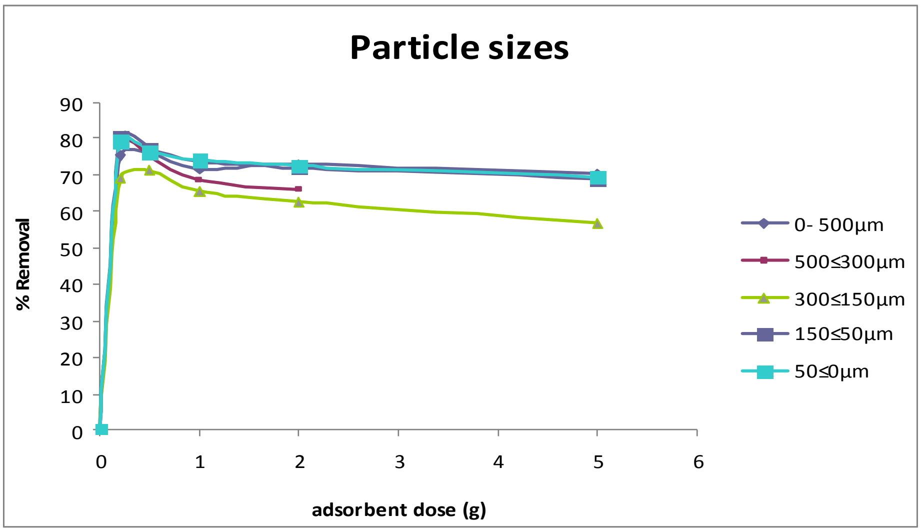

Figure 6: effect of particle size and adsorbent dose on the adsorption of Cu(II) with tassel powder

Conclusion

Removal of copper (II) ions from synthetic water using maize tassel powder was shown in this paper. Maize tassel powder has proven itself as a potential candidate for removal of copper from contaminated waste water. The removal of Cu^{2+} from aqueous solutions by using cheap and readily available waste material offers a good alternative to the currently used expensive methods.

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