

# THE POTENTIAL USE OF MAIZE WASTE FOR THE REMOVAL OF Pb(II) FROM AQUEOUS SOLUTION

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## ABSTRACT

Most available technologies applied in the removal of metal contaminants in aqueous systems use the well established processes of adsorption. Adsorbents currently in use are either too expensive or not readily available for wastewater treatment. There is a need to develop new adsorbents which are readily available at low cost to remove metal contaminants in aqueous system. In this study, we investigated the removal of Pb(II) metal from aqueous solution by means of maize tassel powder using batch adsorption procedures. The utilization of tassels for the removal of toxic heavy metals from effluent solutions would, however, attach some economic value to this waste material. Tassel flowers were collected just prior to harvest, dried under ambient conditions, and then ground using a pestle and mortar. After particle size fractionation, the influence of pH of the metal effluent solution, contact time and concentration of the reaction mixture, on the extent of Pb(II) ion adsorption was studied. AAS was utilized for the metal analyses. The results showed that the best adsorption (with respect to pH) was obtained from neutral pH 7, with percentage adsorptions of approximately 80% for Pb(II). Increased contact time (1 to 24 hours), indicated the establishment of equilibrium conditions between 4-24 h. It was observed that adsorption at low Pb(II) standard concentration of 5 ppm was rapid suggesting that adsorption may have been controlled by external diffusion. By increasing the concentration (from 10-20 ppm) the controlling step of adsorption was suggested to be that of internal diffusion probably within the adsorbent pores. The present study has demonstrated the usefulness of maize tassel as an adsorbent for the removal of heavy metals such as Pb(II) from aqueous solution.

## KEYWORDS

Maize tassel, Pb(II) removal, aqueous solution

## INTRODUCTION

Heavy metals such as cadmium (Cd), lead (Pb) and mercury (Hg) are well known toxic metals that pose a serious threat to the fauna and flora of receiving water bodies. In spite of strict regulations restricting their careless disposal in most countries, these metal cations may still emerge in a variety of wastewater originating from catalysts, electrical apparatus, painting and coating, extractive metallurgy, insecticides and fungicides, photography, pyrotechnics, smelting, metal electroplating, fertilizer, mining, pigments, stabilizers, alloy industries, electrical wiring, plumbing, heating, roofing and building construction, piping, water purification, gasoline additive, cable covering and battery industries (Bachauer, 1973; Low and Lee, 1991; Periasamy and Namasivayam, 1994) and sewage sludge (Bhattaachrya and Venkobachar,

1984).

The acute toxicity of these heavy metals has caused various ecological catastrophes in human history,

such as the "itai itai" disease due to cadmium (Riley and Skrow, 1975). Prolonged effect may cause

other chronic disorders (Huang and Ostovic, 1978).

Various treatment technologies have been developed for the removal of these metals from water.

The

hydrometallurgical technology extracts and concentrates metals from liquid waste using any of the

variety of the processes, such as ion exchange, electrodialysis, reverse osmosis, membrane filtration,

sludge leaching, electrowinning, solvent stripping, precipitation and adsorption (LaGrega et al, 1994a)

A number of adsorbents have been used to remove these metals from aqueous environment and they

include: activated carbon (Huang and Smith, 1981), starch xanthate (Wing and Sessa, 1975), banana

pith (Low et al, 1995) and green algae (Roy et al, 1993). Various agricultural products and by-products,

such as peat moss (Ho and McKay, 1999) straw (Bailey, 1999) and rice husk (Wong et al, 2003) have

also been used for the removal of heavy metals from aqueous solution. Both powdered (Sorg *et al*,

1978) and granular activated carbon (Huang and Smith, 1981) have been used for the adsorptive removal of Pb, Cu and similar "soft" heavy metals. Hydrous oxides such as alumina, iron oxides (Cowan

et al, 1991; Gerth and Brueumner, 1983) manganese oxide (Hasany and Chaudhary, 1984) and titanium oxide (Koryakova et al, 1984) have also been used for the adsorption of the indicated metals.

Also various agricultural products and by-products, such as straw (Patterson *et al*, 1977), corn (Wing

and Sessa, 1998) and rice husks (Wong et al, 2003) have been used for the removal of heavy metals

from solutions. The obvious advantage of this method is the lower costs involved as well as the relative

abundance of these agricultural wastes and by-products in nature.

The cost of the adsorptive metal removal process is relatively high when pure sorbents are used.

Also

strains are placed on those agricultural products that are already in use for other purposes.

Therefore,

there is an increasing trend for substituting pure adsorbents with natural by-products or stabilized solid

waste materials for the development of cost-effective composite sorbents capable of removing heavy

metals from aqueous solutions.

Maize is one of the major agricultural crops in many developing countries. Once the useful nutrient rich

portions of maize plants have been harvested, the remaining portion of the plant is usually either ploughed back into the land or is discarded as agricultural waste. Available information indicates that

tassel (the male flower, found at the top of the plant) may contain some cellulosic hydroxyl group which

can easily bind with positively charged metal ions. Maize tassel, therefore, appears a good candidate for

the adsorption of heavy metals from aqueous solutions. The utilization of tassels for the removal of heavy metals from effluent solutions would, however, attach some economic value to this waste material that currently has no value. The obvious environmental benefit is the utilization of a waste material, whilst cleaning metal contaminated water; and this is of particular relevance to developing countries such as South Africa.

In this study, we investigated the removal of Pb(II) ion from aqueous solutions by means of tassel powder using batch adsorption procedures.

## **MATERIALS AND METHODS**

### **Materials**

All chemicals used were of analytical grade. Acids were obtained from Associated Chemicals Enterprise

(ACE) Pty Ltd, South Africa. Tassel flowers were collected, separated, dried under ambient conditions,

crushed by hand and finally reduced to smaller particles by grinding with a pestle and mortar.

After

particle size fractionation, the effects of contact time, pH of the metal effluent solution, and particle size

of the adsorbent, on the extent of metal ion removal was studied. A shaking water bath was used to

provide a stable temperature and sufficient contact between the tassel powder and the effluent solution.

Potable hand-held combo pH and EC meter (HI 98830) from Hanna Inc. was used for pH adjustments.

### **Instrumentation**

Flame Atomic Absorption Spectrometer (FAAS) Perkin Elmer AA 3030 equipped with automatic background corrector was used for all determinations. Good linearity of the calibration curves was obtained and determination was by reference to the standard curve.

### **Method**

#### **Batch experiments**

1.0 g tassel powder was added into 50 ml of reaction mixture containing 5 ppm of Pb(II) standard in 250

ml Erlenmeyer flask and the pH adjusted to about 1 with 1.0M HCl. The mixture was placed in a shaking

water bath at 25°C. The above procedure was repeated for reaction mixtures containing 10, 15 and 20

ppm of Pb(II) standard. After equilibration the mixture was centrifuged at 3000 rpm for 3 min and the

supernatant filtered with 0.45 µm membrane filter. Pb(II) concentration in the filtrate was subsequently

determined using flame atomic absorption spectrometer (FAAS). Percentage of Pb(II) extracted was

calculated from the difference between the concentrations of cadmium in aqueous solution before and

after equilibration.

To study the effect of pH on adsorption, the above described batch experiment was repeated by adjusting the pH of the adsorption mixture to pH 7 and 12 with 0.01M NaOH.

Time course experiments were carried out by shaking the adsorption mixture at various predetermined

intervals of 1, 4 and 24 h and the rest of the procedure described above repeated.

## **RESULTS AND DISCUSSION**

### **Influence of pH on adsorption**

The influence of pH on the adsorption of Pb(II) ion over a range of concentration is illustrated in figure 1. Pb(II) adsorption increased from pH 1 to 7; thereafter remain relatively constant except for 5 ppm. At pH 7 the four concentrations registered more than 50 % adsorption. As can be seen from the figure 1, quantitative adsorption was at the peak at pH 7.

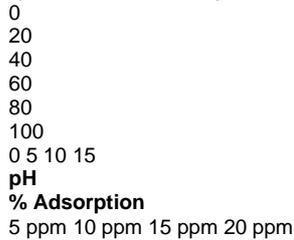


Figure 1: Influence of pH on adsorption at different concentrations

#### Influence of contact time on adsorption

For a given substance to be effective as an adsorbent of metallic species, its sorption rate must be fast and quantitative. Sorption periods of 1, 4 and 24 h were evaluated at different concentrations of Pb(II) standard solutions at different pH levels. Figures 2-4 show the % adsorption of Pb(II) ion by powdered maize tassel at pH 1, 7 and 12. Less than 20% adsorption was exhibited by 5 ppm within 1 h; while at the other concentrations more than 20% adsorption was achieved at the same time (figure 2). Increased adsorption was shown at all concentrations within 4 h as can be seen in figure. 2. Again 5 ppm showed the lowest % adsorption compared to the other concentrations. This pattern is also evident at 24 h, where 10-20 ppm concentrations showed more than 50% adsorption.

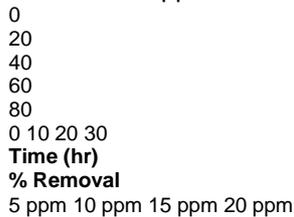
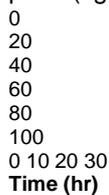


Figure 2: Influence of contact time on adsorption (pH 1)

The trend observed in figure 2 is repeated in figure 3, i.e., increased adsorption with increase in contact time. However, % adsorption at 5 ppm is significantly higher than the adsorption exhibited by the other concentrations at 1 h contact time and 10 ppm at all the contact times. At contact time of 4 h and 24 h, the % adsorption (>80%) of 5 ppm, 15 ppm and 20 ppm are approximately the same. The adsorption at pH 7 (figure 3) is higher than that observed at pH 1 in figure. 2.



### **% Adsorption**

5 ppm 10 ppm 15 ppm 20 ppm

Figure 3: Influence of contact time on adsorption (pH 7)

The adsorption trend observed in figure 3 for 5 ppm and 10 ppm is repeated in figure 4 at all the contact times studied. As can be seen in figure 4, there is a drop in adsorption shown by 15 ppm and 20 ppm at 4 h and 24 contact times.

0

20

40

60

80

100

0 10 20 30

**Time (hr)**

### **% Removal**

5 ppm 10 ppm 15 ppm 20 ppm

Figure 4: Influence of contact time on adsorption (pH 12)

The observed increase in adsorption at these concentration levels can be attributed to the availability of

the active sites within the tassel adsorbent which were not fully occupied at short time interval.

That 5

ppm showed the highest adsorption with increase in contact time is a strong evidence of the availability

of the active sites for binding. As the concentration solution increased the active sites were becoming

fully occupied such that the adsorbent was getting to its saturation point with increase in contact time. It

can also be observed that the adsorption of Pb(II) ion by maize tassel was very rapid in the first 1 h

followed by a gradual process. Equilibrium was attained between 4-24 h. This behaviour suggests the

occurrence of a rapid external mass transfer followed by a slower internal diffusion process which may

be the rate determining step.

### **Influence of concentration on adsorption**

A plot of average adsorption shown by maize tassel adsorbent against concentration is illustrated in

figure 5. It can be observed that the adsorption at low concentration was rapid suggesting that adsorption was controlled by external diffusion. By increasing the concentration the controlling step of

adsorption became internal diffusion with adsorbent pores, and thus the observed slow process of

adsorption with increase in concentration.

Average adsorption

0

50

100

0 5 10 15 20 25

**Concentration (ppm)**

### **% Adsorption**

Average adsorption

Figure 5: Influence of concentration on adsorption

## **CONCLUSIONS**

The ability of maize tassel to remove varied concentrations of Pb(II) through batch experiments was

demonstrated. Quantitative adsorption within pH of 1, 7 and 12, good sorption capacity and high sorption rate (4-24 h) of the adsorbent, demonstrate its potential application for the removal of trace

metals from aqueous solutions and environmental waters in particular. Furthermore, as little as 1.0 g of adsorbent gave above 75 % adsorption. The application of the adsorbent to the removal of heavy metals from wastewater and river water will show the full potential of maize tassel as a useful and cost-effective adsorbent.

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