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Adsorption of Zinc (II) from Electroplating Industrial Effluents using Coffee Bean Husk as Low –Cost Adsorbent

Dr. T Yasodha[1*] and R Sasirekha[2]

[1]Department of Biotechnology, PGP College of Arts and Science, Namakkal, Tamil Nadu, India

[2]Tamil Nadu Waste Management Laboratory, Chennai, India

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***For Correspondence**

Dr. T Yasodha, Head,
Department of Biotechnology,
PGP College of Arts & Science,
Namakkal, Tamil Nadu 637207, India,
Tel: +91 -8148114119.

E-mail: btmbty@gmail.com

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ABSTRACT

Zinc is widely used in electroplating industries for coating the surface of wind mill components, electrical goods, household goods, hand pumps and door locks etc. The basic processing units viz., cleansing, preplating, post plating and rinsing are mainly polluting the nearby water bodies. Various technologies available for the removal of Zn(II) from aqueous solutions include ion exchange solvent extraction, solvent extraction, chemical precipitation etc., But these methods are cost intensive and are unaffordable for large scale treatment of waste water rich in Zn(II) for developing country like India. The present study is focused on identifying a low cost adsorbent for Zn (II) adsorption from electroplating industrial effluent. There are many potential alternative to existing treatment technologies. Hence present study is to envisage the effect of pH, adsorbent dose and agitation time to the extent of Zn (II) adsorption on activated coffee bean husk from zinc plating industrial effluent. Sorption data had been correlated with both Langmuir and Freundlich adsorption isotherm models.

INTRODUCTION

Agro – industrial wastes of major environmental concern are the coffee processing by-products. Several wastes, viz., cherry and parchment husk are generated during processing of coffee fruits and coffee bean. Pectin of coffee bean husk has some cation exchange properties. Pectin's in the form of galacturonic oligosaccharides are similar to ion-exchange resins. They are able to form complexes with bivalent and hexavalent metals [1]. With this background, the coffee bean husk has been selected as bio sorbent to adsorb Zn (II) from electroplating effluents in the present investigation.

METHODOLOGY

Preparation of Adsorbent

The coffee bean husk consists of more lignin in the wet and dry condition. Hence to delignify the coffee bean husk was treated with 0.1 N sodium hydroxide solution for 10 hrs [2]. The coffee bean husk was treated with 0.1 N sulphuric acid for about 4-5 hrs, to remove the alkalinity and washed with distilled water till the wash water became colorless. The bio sorbent was dried in sun light and stored in desiccators.

Collection of Effluents

Electro plating wash water from the industry was collected in the plastic containers as per standard methods [3]. The industrial effluent of zinc plating units was analyzed as per standard methods and results are predicted in **Table 1**.

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Table 1. Characteristics of zinc plating industrial effluent.

Parameters	Values
pH	4.1-5.5
DO	6.8-7.6
So4	0.53-1.01
Cl2 (mg/l)	0.40-0.80
TSS(mg/l)	3.8-5.4
TDS((mg/l)	21-23.5
Zn (mg/l)	0.05-232
BOD @ 20°C (mg/l)	170-262
COD (mg/l)	248-431

To study the adsorption capacity of the coffee bean husk, batch experiment was conducted. 100 ml of sample was collected into each conical flask. To these flasks an adsorbent of 1 g/l was added and agitated thoroughly for 45 minutes on orbital shaker at 180 rpm. The suspension was filtered through Whatman filter paper No:41, and the filtrate was analyzed for residual Zn (II) concentration spectrophotometrically. In the present research work, the effect of pH, contact time, adsorbent dose and modeling for adsorption data were studied. Initial pH was adjusted with 0.1 N HCl/H_2SO_4. All the experiments were conducted at 32°C.

RESULTS

Effect of pH

pH affects the adsorption process through dissociation of functional groups on the adsorbent and adsorbate. pH is an important controlling factor in adsorption process. Thus the role of hydrogen ion concentration was studied in the present investigation, covering range of 2-8. The effect of pH on the adsorption of Zn (II) is shown in **(Table 1)**. It is observed that the higher pH 4-8 has no effects on metal adsorption. At pH 3.5 Zn (II) removal was increased 55% and at pH 2.5, metal sorption was maximum up to 97%. At lower pH, large number of H^+ions neutralize the negatively charged coffee bean husk or convert a neutral group to a positively charged group and enhanced the adsorption of Zn (II) species. The surface properties of the adsorbent and metal speciation are affected by the pH of the metal solution. The uptake of the metallic cations by adsorbent is reduced at pH below 3 and above 8; lowest at its isoelectric ph and highest at alkaline pH range [4]. The equilibrium is attained at pH 2 in 120 minutes of agitation time. Similar results were observed in pyrolysed bagasse char as low cost adsorbent system [5].

Effect of Adsorbent Dosage

Batch adsorption studies were carried out at 32°C and at pH 2.5. The adsorbent dosage was varied from 10-50 mg and the removal of Zn (II) increased from 30-80%. This is to be expected because for a fixed effluent concentration increasing total adsorbent doses provides a greater surface area or adsorption site and thus the adsorption increases with adsorbent dosage as given in the **(Table 2)**. Increase in adsorbent dosage increased the adsorption of Zn (II) species. This kind of observation was reported with the removal of Pb using lignite [6].

Table 2. Kinetic modeling for the adsorption of Zn (II).

	Log (qe-q) mg/100 ml			
Time(mins)	0.04	0.16	0.56	1.16
30	-1.6959	-1.6353	-1.5656	-1.5218
60	-1.8239	-1.7851	-1.7668	-1.6756
90	-2.0132	-1.8760	-1.8531	-1.7551
120	-2.1049	-1.8586	-2.2118	-2.0068
150	-2.5218	-2.0601	-2.5208	-2.3001

Effect of Agitation Time

The agitation time along with temperature and pH for the uptake of Zn (II) from effluent by coffee bean husk was recorded. Biosorption was increased from 21 to 85% during 30 to 120 minutes. The equilibrium was attained in 150 min at 32°C and at pH 2. The increase in agitation time was increased the adsorption capacity of coffee bean husk may be due to the increased intra particle diffusion occurring at long shaking time **(Table 3)**.This view is in accordance with results of Zn and Ni removal by saw dust [7].

Table 3. Data for Langmuir adsorption isotherm.

S.no	1/(x/m)	1/Ce
1	0.0511	0.00512
2	0.02164	0.00406
3	0.01820	0.00350
4	0.01327	0.00301

Kinetic Modelling

The adsorption study had been described the solute uptake rate which in turn controls the residence time of adsorbate uptake at the solid-solution interface. The adsorption kinetics of Zn (II) adsorption on to activated coffeebean husk . follows first order rate expression given by Largergen.

Log(qe-q)= log qe –Ka t/2.303

Where Ka (sec^{-1}) is the rate constant of adsorption.

q and qe are the amount of Zn (II)adsorbed (mg/g) at time't' and equilibrium time, respectively.

When log(qe-q) versus 't' is plotted, the linear plots show the applicability of Lagergren equation for Zn (II) adsorption. The Ka values at different initial concentrations are calculated from the slopes of linear plots and are given in **Table 3**.

ADSORPTION ISOTHERM

The study of adsorption isotherms are helpful in determining the adsorptive potentiality of an adsorbent. Hence Langmuir and Freundlich adsorption isotherm models were applied. The Langmuir equation correlates the amount of adsorbate adsorbed with the equilibrium aqueous concentrarion. The linear transformation of Langmuir equation (8) is given as:

1/x/m =1/b+1/abC

Where 'x' is the amount of Zn (II) adsorbed in mg/100 ml, 'm' is the weight of the adsorbent (g), Ce is the residual concentration of Zn (II) at equilibrium in mg/100 ml. Langmuir constants 'a' and 'b' are the measures of maximum adsorption capacity and the energy of adsorption is given in the **Table 3**.

R L = 1/1 +bCo

Where, Co is the initial concentration of the adsorbate and 'b' in the Langmuir constant. RL>1 indicates unfavorable isotherm, RL=1 represents linear isotherm, 0<RL <1 indicates favorable isotherm, RL=0 indicates irreversible isotherm.

The values of RL <1, obtained in the study indicate the capability of Langmuir adsorption isotherm. The linear form of Freundlich equation (9) is represented as:

Log x/m = log Kf + 1/n log Ce

Where 'x' is the amount of Zn (II) adsorbed in mg/100 ml. 'm' is the weight of adsorbent(g). Ce is the residual concentration of Zn (II) at equilibrium in mg/100 ml. Kf and 1/n are Freundlich constants related to the adsorption capacity and adsorption intensity respectively and are evaluated by least square fitting of the data by plotting log x/m vs log Ce with the slope of 1/n and intercept of log Kf. The values of adsorption intensity 1/n << 1 reveals the applicability of this adsorption isotherm. The values of Kf are given in the **Table 3**.

Table 4. Data for Freundlich isotherm.

S.no	LogCe	Log (x/m)
1	1.5458	2.38
2	1.7050	2.4572
3	1.8361	2.4773

The linear form of Freundlich equation is represented as follows:

Log (x/m)= log Kf +1/n logCe

Where,

'x' is the quantity of Zn (II) adsorbed in mg/100 ml

'm' is the weight of adsorbent (g)

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Ce is the residual concentration of Zn (II) at equilibrium in mg/100 ml.

Kf and 1/r are Freundlich constants related to the adsorption capacity and adsorption intensity, respectively.

The values of adsorption intensity 1/n<<1 reveals the application of this adsorption isotherm. The values of Kf are given in the **Table 4**.

CONCLUSION

Biopsorptive potentiality was influenced by the pH, amount of adsorbent and agitation time. Hence in the present study the adsorption of Zn (II) by activated coffee bean husk had been supported that it is an effective low cost adsorbent for the removal of Zn (II) from plating effluent. Langmuir and Freundlich adsorption isotherm correlate the equilibrium adsorption data. The adsorption of Zn (II) followed Lagergren first order kinetics. Thus the coffee bean husk had been found to be very effective biosorbent for the efficient removal of Zn (II) from the effluent. Results of the experiments and modeling would prove useful in designing and fabricating an efficient treatment plant for Zn (II) rich effluent.

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