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Research Article

BIOSORPTION OF ZINC (II) IONS FROM AQUEOUS SOLUTION USING *BORASSUS FLABELLIFER* FIBER

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Abstract

The effective removal of heavy metals from the sugar industry effluent among the most important issue of the many industrialized countries. Removal Zn^{2+} from aqueous solution where studied using palm fiber. Batch adsorption was performed as a function of pH, initial metal ion concentration, equilibrium time and bio-sorbent dose. The optimum pH obtained from results found to be 5. The maximum contact time for the equilibrium concentration is 180 minutes. The biosorbent dose of 6g. The maximum efficiency of removal of metal ion by bio-mass is 79 %.The results are fit exactly by both Langmuir and freundlich isotherm model.

Keywords: Biomass; Biosorption; Isotherm; Kinetics; Removal of Zinc.

1. Introduction

The presence of heavy metals in the environment has been of great concern because of their increased discharge toxic nature and other adverse effect on receiving water bodies [1]. Therefore growing attention is being paid to remove heavy metals from industrial waste water to produce the environment and human health [2]. Hence developing strategies for the control and reducing the level of heavy metals to their permissible limit in waste waters are major challenges for environmental scientist [3]. Commonly there are many methods for the removal of heavy metal ions from the solution such as chemical precipitation, solvent extraction and membrane process[4]. There are often expensive, incomplete metal removal, high reagent and energy requirement, and toxicity required disposal[5]. The search for new technology to remove toxic metal from waste water has direction to biosorption[6]. Biosorption techniques utilize any natural form of biomass to passively sorbs and immobilize solubilized heavy metal ions[7].

Biosorption can be defined as the ability of biological materials to accumulate heavy metals from waste water through metabolically mediated or physicochemical pathways of uptake[8]. The biosorption process [9] involves a solid phase (sorbent or biosorbent; biological material) and a liquid phase (solvent, normally water) containing a dissolved species to be sorbed (sorbate, metal ions). Due to higher affinity of the sorbent for the sorbate species, the latter is attracted and bound there by different mechanisms. The process continues till equilibrium is established between the amount of solid-bound sorbate species and its portion remaining in the solution[10]. The degree of sorbent affinity for the sorbate determines its distribution between the solid and liquid phases. The biosorption is an emerging and attractive technology used for the removal of heavy metal from industrial wastewater and it presents as main advant ages the reusability of biomaterial, low operating cost, improved selectivity for specific metals of interest and short operation time[11,12].

The borassus flabellifer fiber is known as one of the most promising biosorbent because of the enormous abundance worldwide bare land and relative ease in collection. This new material was chosen as boisorbent in this study as it is natural easily available and thus a low cost biomass for dissolved metal ion. Also this material has shown good biosorption ability for Pb^{2+} Cd^{2+} and Cr^{2+} metal ion in our earlier communication.

The objective of the present study to remove zinc from aqueous solution using *Borassus flabellifer* fiber as adsorbent material. The effect of various parameters such as pH, initial concentration, adsorbent dose and equilibrium time are studied. The pseudo first order kinetics model is applied to the kinetics of the adsorption. The data are fitted to Langmuir and freundlich isotherm models.

2. Materials and Methods

2.1 Collection and preparation of biomass

The *borassus flabellifer* fiber was collected from the road side of Sadayangal village, Valangaiman (T.k), Tiruvarur (Dt). The collected biomaterial is washed extensively in running river water and deionized water to remove the dirt and other impurities. The dirt-free fiber were dried in the shade. Then the fiber was crushed using pulveriser. Then the fiber powders were sieved using 50 mesh and fine biomass obtained was used as biosorbent without any pretreatement for Zn^{2+} adsorption[13].

2.2 Preparation and analysis of Zn^{2+} solution

For biosorption experiments, stock Zinc solution of 1000mg L^{-1} was prepared by dissolving an appropriate amount of Zinc Sulphate in distilled water. Zn^{2+} solution of different concentration were prepared by adequate dilution of stock solution with distilled water Zn^{2+} contents in the solutions were determined by Atomic Absorption spectrophotometer[14].

2.3 Batch biosorption experiments

The affinity of biomass to adsorb Zn^{2+} ions was studied in batch experiments. In all sets of experiments fixed volume of Zn^{2+} solution (50ml) was stirred with desired biosorbent dose (5g) of 50 mesh size at $33+1^{o}$c and 650 rpm for 3 hours. Different conditions of pH (1, 2, 3, 4, 5, 6,7), initial metal concentration(20, 40, 60, 80, 100 ppm) and contact time (30, 60, 90, 120, 150, 180, 210mins)with 30min increased were evaluated during study. The solutions were separated from biomass by filtrations through whatmann 40 filter paper.

3. Results and Discussion

Effects of contact time, pH, Initial metal ion concentration and biosorbent dose on Zn^{2+} sorption capacity of Palm Fiber powder were investigated. All the experiments were repeated thrice to confirm the results the average values were presented.

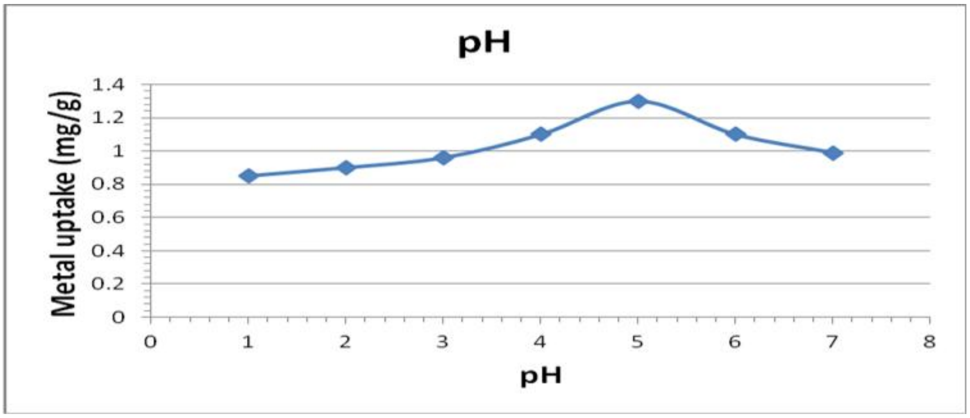
3.1 The effect of pH on the sorption of zn^{2+} ion on to *Borassus flabellifer* fibre powder

Batch equilibrium studies are carried out at different pH in the range 1-7. It was given in the Table 1 and the effect of metal uptake efficiency (mg/g) to initial pH a graph was plotted and shown in the Fig. 1. The pH is one of the important parameter for adsorption of metal ion from aqueous solution because it affect the solubility of the metal ion and for governing bio sorption materials by sorbents. It was found that optimum metal uptake efficiency of Zn^{2+} ions occurs at pH 5.

Table 1 Effect of initial solution pH of Zn^{2+} on the metal uptake, Time 60 min, Biosorbent dose 6g/L, Volume of the solution 50 mL, Temperature 33 ± 1^{o}c, using biomass *Borassus flabellifer* fiber powder

Metal ion concentration (ppm)	pH	Metal ion concentration after Adsorption (ppm)
20	7	14.1
20	6	13.4
20	5	12.2
20	4	13.4
20	3	14.2
20	2	14.6
20	1	14.9

Fig. 1 Effect of initial solution pH on the metal uptake, Time 60 min, Biosorbent dose 6 g/L, Volume of the solution 50 mL,



3.2 Effect on biosorbent dose:

The concentration of both metal ion and the biosorbent is the significant factor to be considered for effective biosorption. The effect of solid to liquid ratio on the Zn^{2+}sorption was studied by keeping all other parameters constant ranging from 3 g/L to 15 g/L were used to determine the suitable quantity of biomass for maximum sorption. The values were presented in the Table 2 and the graph was plotted for removal efficiency (%) against biosorbent dose (g/L) shown in the Fig. 2. The optimum dose was found to be 6g in studies on biosorption of Zn^{2+} from aqueous solution.

Table 2 Effect of adsorbent dose on removal efficiency (%) of Zn^{2+} Time 60 min pH 5, Volume of the solution 50 mL, Initial metal ion concentration 20 mg/L, using biomass *Borassus flabellifer* fiber powder.

Metal ion concentration (ppm)	Biosorbent dose (g/L)	Metal ion concentration after Adsorption (ppm)
20	3	14.1
20	6	12.2
20	9	12.4
20	12	12.5
20	15	12.4

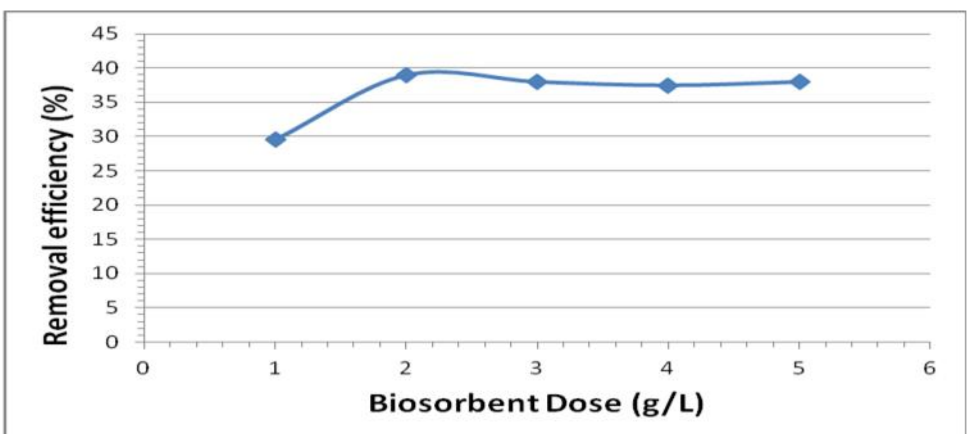


Fig. 2 Effect of adsorbent dose on removal efficiency (%) of Zn^{2+}, Time 60mts , pH 5, Volume of the solution 50 mL, Initial metal ion concentration 20 mg/L

3.3 Determination of equilibrium time

Equilibrium time is maximum time taken by the sorption experiment to achieve equilibrium after which no further metal uptake is adsorbed. The result for the determination of equilibrium time was given in the Table 3 and the graph was plotted between removal efficiency with respect to time is shown in the Fig.3. From the figure that the contact time significantly affects the metal uptake and sharp increases was observed then attain equilibrium at 180 minutes.

Table 3 Equilibrium time for Zn^{2+} biosorption, pH 5, Biosorbent amount 6 g/L, volume of the solution 50mL, Initial metal ion concentration 20 mg/L, Temperature 30±1^{o}C, using biomass *Borassus flabellifer* fiber powder.

Metal ion concentration (ppm)	Time (min)	Metal ion concentration after Adsorption (ppm)
20	30	16.2
20	60	12.6
20	90	10.1
20	120	7.2
20	150	5.5
20	180	4.2
20	210	4.2
20	240	4.2

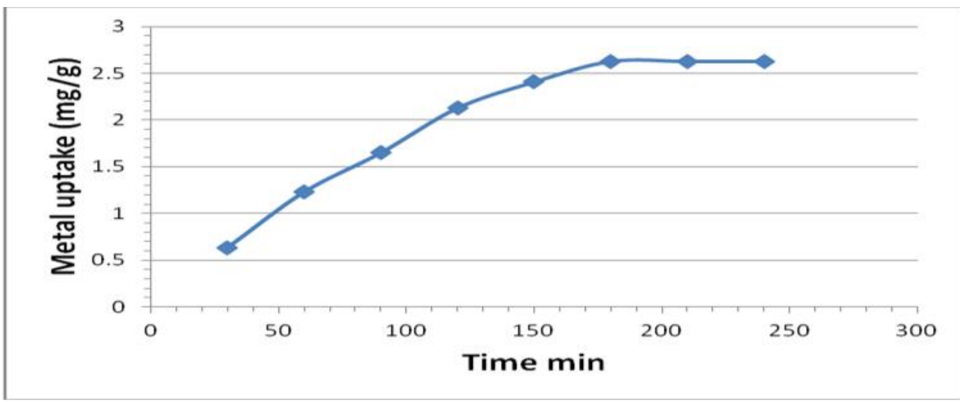


Fig. 3 Equilibrium time for Zn^{2+} biosorption ,pH 5, Biosorbent amount 6 g/L, volume of the solution 50mL, Initial metal ion concentration 20 mg/L

3.4 Effect of initial metal ion concentration

The rate of sorption is function of initial concentration of metal ion which makes it an important factor to be considered for effective bio sorbent. The initial metal ion concentration provide driving force overcome mass transfer ions between aqueous and solid phase. The initial concentration was changed in the range of 20 to 100 ppm by keeping all other parameter constant. The results were shown in the Table 4 and the graph was plotted in the Fig.4.The sorption capacity increase with increasing initial metal ion concentration for Zn^{2+}sorbent.

Table 4 Effect of initial metal ion concentration on biosorption of Zn^{2+}, Time 60 min, pH 5, Volume of the solution 50 mL, Biosorbent amount 6g/L, Initial metal ion concentration 20 mg/L to 100 mg/L, Temperature 30±1^{o}c, using biomass *Borassus flabellifer* fiber powder.

Metal ion Concentration (ppm)	Metal ion Concentration after Adsorption (ppm)
20	4.2
40	10.8
60	19.8
80	31.2
100	45.0

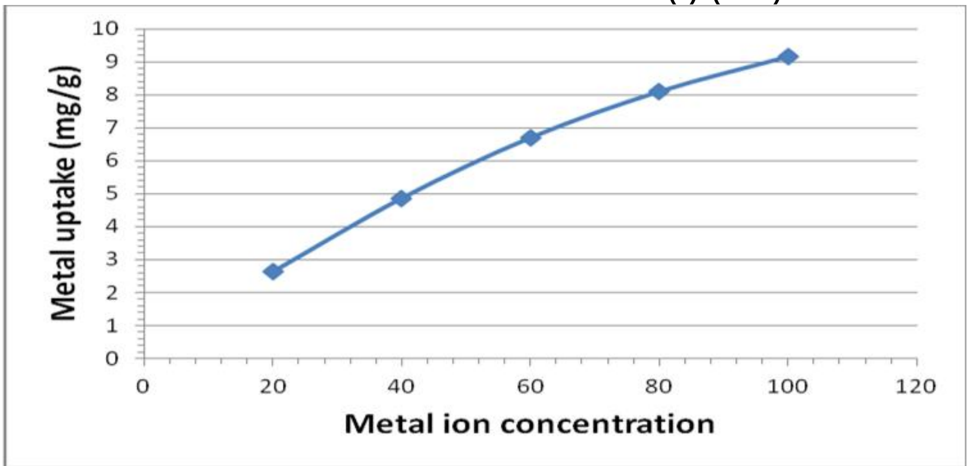


Fig. 4 Effect of initial metal ion concentration on biosorptionof Zn^{2+}, Time 60mts, pH 5, Volume of the solution 50 mL, Biosorbent amount 20g/L, Initial metal ion concentration 20 mg/L to 100mg/L

3.5 Pseudo first order kinetic model

Generally kinetic models have been used to test the experiment data to investigate the mechanism of bio-sorption and potential rate controlling step such as mass transfer and chemical reaction process. The transistance behavior of batch bio-sorption process is analyzed using pseudo first order kinetic model.

The model is as below

$$\log(q_e - q_t) = \log q_e - (kT / 2.303)$$

$\log(q_e-q_t)=\log q_e-(kT/2.303)$

Where q_e is the mass of the metal ion adsorbed (mg/g) at equilibrium time,

q_t is the amount of the metal ion adsorbed at time t (min^{-1}),

K is the rate constant of adsorption.

The sorption coefficient and equilibrium capacity qe can be determined from the linear plot of log (q_e-q_t) versus time from the table-4 for different concentration from the Fig. 5 to Fig. 9. It was evident that the linear plots at different concentration show the applicability of the Lagergran equation, k values were calculated from the slopes of the linear plot and was present at Table 6. The results indicated that the metal ion concentration has no significant effect. The coefficient correlation of R^2 is approximately 0.992 and the kinetic model was approximately 1. The fact suggests the sorption of Zn^{2+}ion follows first order kinetic mode.

Table 5 Equilibrium time for Zn^{2+} biosorption , pH 5, Volume of the solution 50 mL, Biosorbent amount 6 g/L, initial metal ion concentration 20mg/L

Metal ion Concemtration (ppm)	Time (min)								qe	C_e/q_e
	30	60	90	120	150	180	210	240		
20	16.2	12.2	8.9	6.6	5.5	4.2	4.2	4.2	2.633	1.595
40	33.8	28.4	24.4	21.2	17.8	10.8	10.8	10.8	4.866	2.219
60	53.1	42.0	33.1	26.5	24.2	19.8	19.8	19.8	6.700	2.955
80	72.0	58.4	53.2	39.4	35.5	31.2	31.2	31.2	8.133	3.836
100	90	75	63	54	50.9	45	45	45	9.166	4.909

Table 6 K Values from pseudo first order kinetics for 10ppm to 50 ppm

Metal ion Concentration (ppm)	K values
20	8.3 X 10^{-3}
40	7.8X 10^{-3}
60	7.6 X 10^{-3}
80	8.1 X 10^{-3}
100	7.6 X 10^{-3}

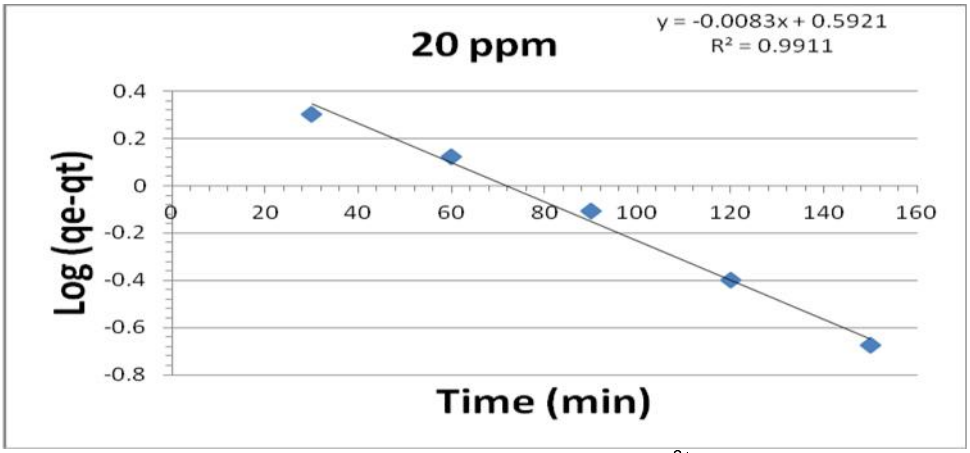


Fig. 5 Linearised pseudo-first order biosorption kinetics of Zn^{2+} for 20 ppm using biomass *Borassus flabellifer* fiber powder.

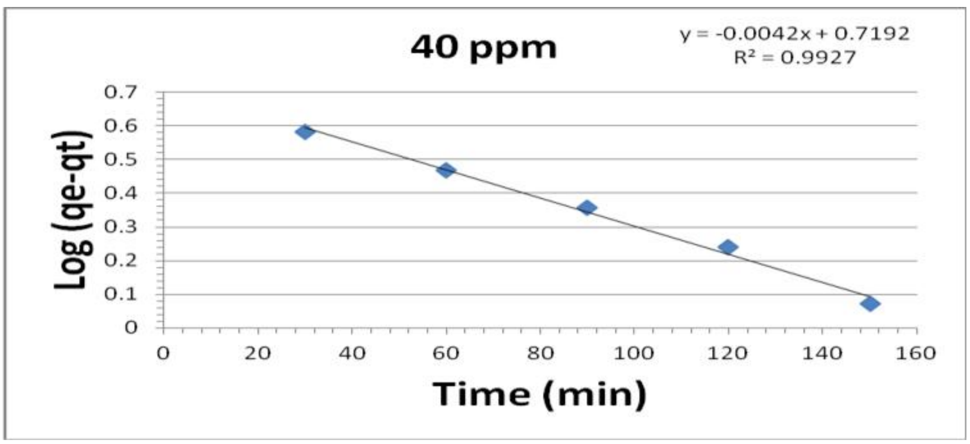


Fig. 6 Linearised pseudo-first order biosorption kinetics of Zn^{2++} for 20 ppm using biomass *Borassus flabellifer* fiber powder.

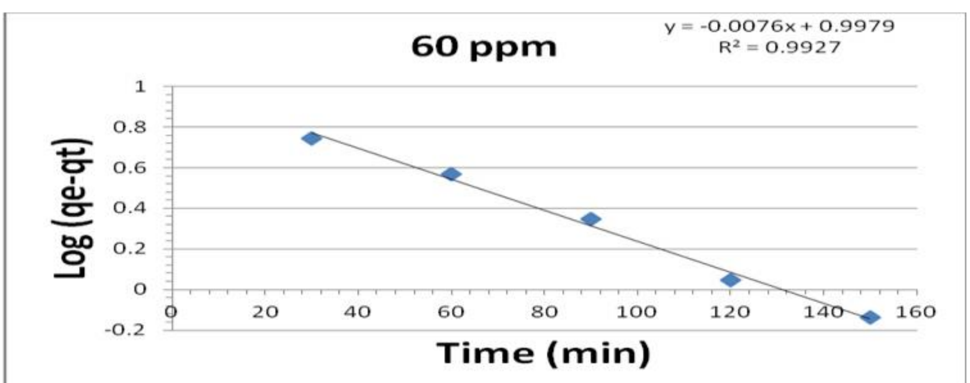


Fig. 7 Linearised pseudo-first order biosorption kinetics of Zn^{2+} for 20 ppm using biomass *Borassus flabellifer* fiber powder.

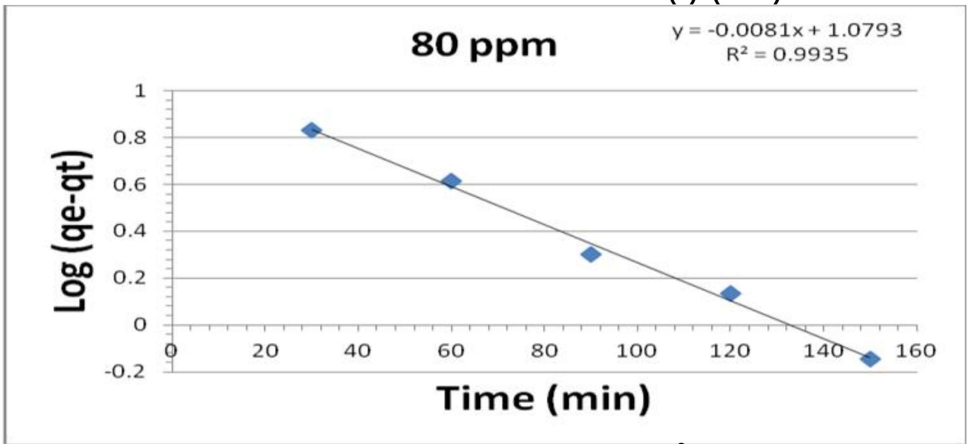


Fig. 8 Linearised pseudo-first order biosorption kinetics of Zn^{2+} for 20 ppm using biomass *Borassus flabellifer* fiber powder.

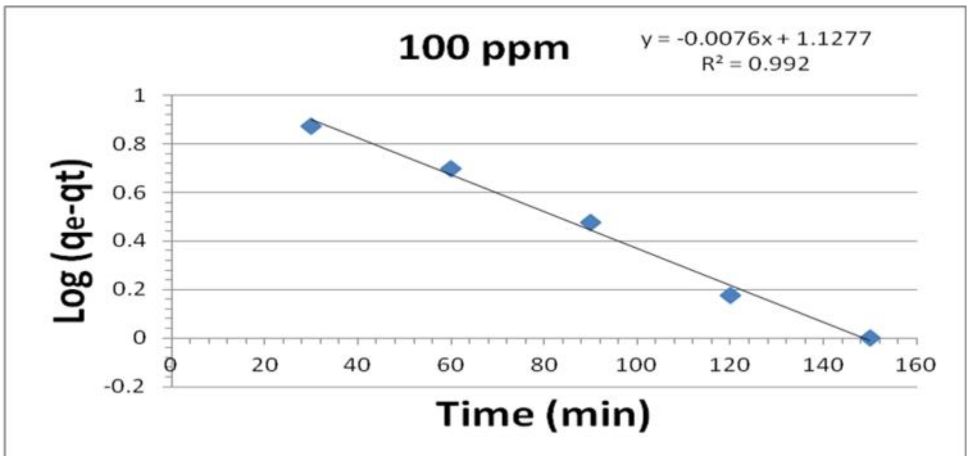


Fig. 9. Linearised pseudo-first order biosorption kinetics of Zn^{2+} for 20 ppm using biomass *Borassus flabellifer* fiber powder.

Modeling the equilibrium data is the fundamental for the industrial application of biosorption. Since it gives information for designing and optimizing operating procedure. It is also helpful to comparing different biomaterial and different operating condition. To find the relation between aqueous concentration C_e and sorbed quantity q_e at equilibrium mostly sorption isotherms model fitting data Langmuir and freundlich widely used. Langmuir parameters can be determined from the linearized form of the equation given below

$$C_e / q_e = 1 / q_{max} b + C_e / q_{max}$$

Where q_e is the metal ion adsorbed (mg/g),

C_e is the equilibrium concentration of metal ion solution,

q_{max} and b is the Langmuir constant.

The Freundlich model is expressed as

$$q_e = k_f c_e^{1/n}$$

Above equation can be rearranged into following form

$$\ln q_e = \ln k_f + 1/n \ln C_e$$

Where, q_e is the metal ion adsorbed (mg/g),

C_e is the equilibrium concentration of metal ion solution (mg/L),

K_f and n are the Freundlich constant. Langmuir and Freundlich plots were arrived using the Table 5 and the plot was shown in Fig.10 and Fig.11. It appears that Langmuir and Freundlich model both best fit the experimental results over the experimental range with good correlation coefficient.

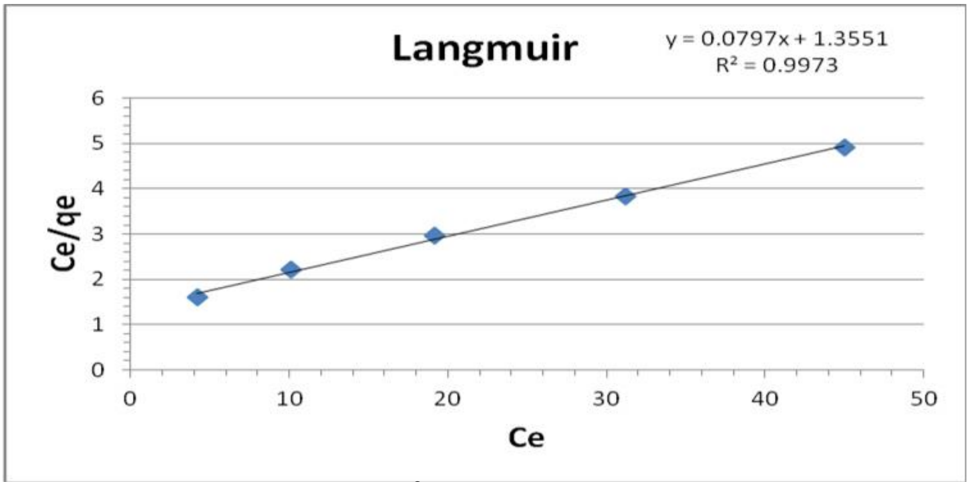


Fig. 10 Langmuir isotherm plot of Zn^{2+} adsorption on *Borassus flabellifer* fiber powder

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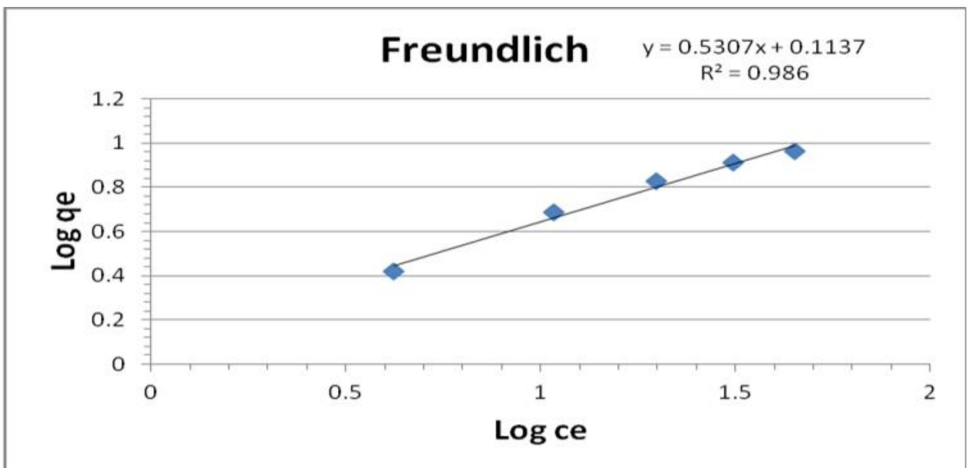

Fig. 11 Freundlich isotherm plot of Zn^{2+} adsorption on biomass *Borassus flabellifer* fiber powder.

4. Summary and Conclusion

The effect of different factors on the sorption abilities of inexpensive fiber *Borassus flabellifer* powder was studied for the removal Zn^{2+} from aqueous solution. The following conclusion drawn from the present studies *Borassus flabellifer* powder is a suitable material for Zn^{2+} adsorption. pH, Biosorbent dose, Equilibrium time and Initial metal ion concentration highly affect the over all metal uptake capacity of biosorbent. The sorption was pH dependent and sorption capacity increased in pH value upto 5. After that there is a decrease in sorption. The optimum time was observed to be 180 min. with sorption capacity of 2.6 mg/g. The optimum dosage was 6 g/L. Present result show that both Freundlich and Langmuir model fits better for the adsorption equilibrium data. In the examined concentration range 20-100 mg/L the results also reveals, it follows pseudo first order kinetic model. So *Borassus flabellifer* powder can be used to remove heavy metal Zn^{2+} from the effluent. Engineering technologies can be developed by using the results of isotherm model for removal of effluent in most efficient way.

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