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Multiple Linear Regression Model for Removal of Iron Using Low Cost Adsorbents

Dr. C.G. Hemamalini[1,*], P. Lavanya[2], S. Kesana[3], R. Kishore Kumar[4], R. Ajith Kumar[5]

Author Affiliations:
[1]Professor, Department of Civil Engineering, Easwari Engineering College, Chennai. Tamil Nadu 600089, India.
[2-5]UG Student, Department of Civil Engineering, Easwari Engineering College, Chennai. Tamil Nadu 600089, India.

***Corresponding Author:**
Dr. C.G. Hemamalini, Professor, Department of Civil Engineering, Easwari Engineering College, Chennai, Tamil Nadu 600089, India,

E-mail: cghemamalini72@gmail.com

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Abstract

The removal of iron from groundwater using low cost adsorbents to serve the rural places and to provide decentralized water treatment plant is the main focus of the study. The low cost adsorbents which are prepared from agricultural waste such as rice husk and sugarcane bagasse (Saccharum officinarum) and medicinal plants such as tulsi leaves (Octimum Sanctum) and vettiver (camel grass) were used. In this study, batch adsorption of Fe (III) ions onto rice husk ash, sugarcane bagasse, tulsi powder and vettiver was investigated. Batch test was conducted by varying different variables such as contact time, concentration and dosage. Fe (III) adsorption equilibrium was analysed with multiple linear regression analysis. The removal efficiency of rice husk ash, sugarcane bagasse, tulsi powder and vettiver were found to be 91.02%, 94.90%, 75.52% and 74.84% respectively.

Keywords: Iron removal, Groundwater, Adsorption, Rice husk, Sugarcane bagasse, Tulsi powder, Vettiver.

1. INTRODUCTION

Sustainability of good health depends upon the purity of water. However groundwater may be exposed towards to contamination by various anthropogenic activities such as agricultural, domestic and industrial. Groundwater quality problem are typically associated with high level of iron concentration. Iron is the second most abundant metal in earth's crust. The present study is an attempt for the removal of iron from groundwater using low cost adsorbents to serve the rural places. The desirable and permissible limit of iron in drinking water is 0.3 mg/l and 1 mg/l respectively as per BIS.(10500:1991) Natural water contains variable amounts of iron depending on the geological area and other chemical components of waterway. Iron in groundwater is normally present as bivalent form, which is soluble. It is easily oxidized to ferric iron or insoluble iron upon exposure to air (Brian Oram 2012) .

The concentration of iron in groundwater varies from 0 to 50 mg/l and the highest value of iron was found in a hand pump at Bhubaneswar was 49 mg/lit (National research council 1979). In Tamilnadu, salem and namakkal district has greater than 1 mg/l of iron concentration. Iron concentration in residential areas of Chennai city ranges between 0.05 to 21 mg/l (Cpreec.org/173.htm.). The iron concentration in groundwater varies between 1 to 10 mg/l in SRM Easwari Engineering College. Consuming water which contains excess iron causes health hazards to human being (Berbenni P et. al 2000). However, iron present in water may cause change in taste and staining clothes. Excess Iron in water causes deposits of iron in pipelines, pressure tanks, water heaters and water softeners and also causes pressure drop in the system where cast iron, steel and galvanized iron pipes are used for water distribution (Das B.P.Hazarika et. al. 2007). Various methods such as electro coagulation, reverse osmosis, ion exchange, membrane separation and adsorption can be used for removal of iron.

Adsorption is the most effective and adaptable method. Adsorption is the process of adhesion of adsorbate on the surface of adsorbent. Adsorption is a surface phenomenon more the surface area of the adsorbent and large will be the adsorption capacity of the adsorbate(Monik Kasman et. al 2012).

The effect of various parameters such as contact time , concentration and dosage were investigated.

2. MATERIALS AND METHODS

Adsorbent: Rice husk was collected and the rice husk ash (RHA) was prepared by placing it in muffle furnace under controlled temperature of 500^{o}C for 3 hours. Sugarcane bagasse (SB) was collected and washed thoroughly with distilled water to remove dirt and dried in sunlight and was powdered. Tulsi leaves were collected, dried and powdered. Vettiver was collected and used.

Synthetic iron solution: The synthetic iron solution was prepared from ferrous ammonium sulphate. The required amount of ferrous ammonium sulphate was dissolved in concentrated nitric acid and distilled water for preparing different concentrations.

Instrumentation:

Jar Test Apparatus

The batch experiments were carried out in jar test apparatus to determine the adsorption isotherms of metal ions by mixing fixed amount of adsorbent with the iron solution in a glass flask. The flasks were shaken at a constant rate allowing sufficient time for adsorption equilibrium. The adsorption experiment were carried out varying initial concentration, dosage and contact time.

UV-VIS Spectrophotometer

The mixture is then filtered and the supernatant liquid is used to determine the final concentration of the synthetic iron solution using UV-VIS Spectrophotometer.

Adsorption and Removal Efficiency:

The amount of Fe(III) adsorbed per unit mass of the adsorbent (q_e) and the removal efficiency (%) was calculated by equation (1) and (2) respectively

$$q_e = \frac{(C_i - C_e)V}{m} \qquad (1)$$

Where C_i and C_e are the initial and equilibrium concentration (mg/L), m is the mass of the adsorbent (g) and V is the volume of the solution (mL). Metal ion removal percent (%MR) was calculated using equation(Leena Deka and Krishna G.Bhattacharyya 2015)

$$\%MR = \frac{(C_i - C_e)}{C_i} * 100 \qquad (2)$$

Influence of contact time

Batch test is carried out and the effect of contact time on the adsorption of iron was studied. The contact time is taken as 30min, 45 min, 60 min, 75 min, and 90min with different concentration such as 10, 15, 20, 25, 30 mg/l and dosage of adsorbents as 0.3, 0.5, 1, 2, 3 g/0.2lit. The fig.1 is plotted by varying contact time with concentration of iron solution as 10mg/l and dosage of adsorbents as 0.3 g/0.2 lit. As the contact time increases the amount of iron adsorbed by the adsorbents increases is shown in fig.1

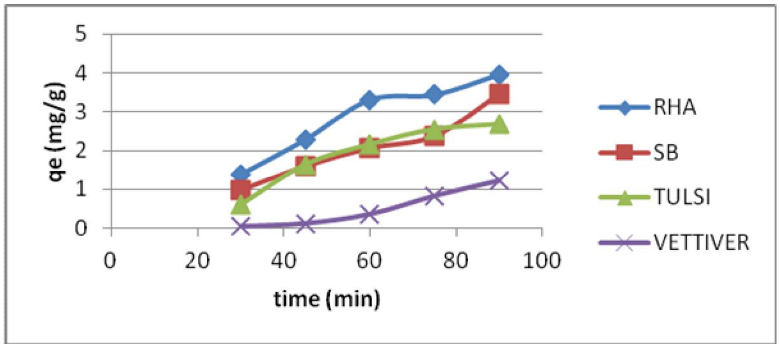

Figure 1:

Influence of dose

The weight of RHA, SB, Tulsi powder and Vetiver is varied from 0.3 to 5g/0.2 lit with different concentration such as 10, 15, 20, 25, 30 mg/l and contact time as 30min, 45 min, 60 min, 75 min, and 90min. The fig.2 is plotted with varying dosage with concentration of iron solution as 10mg/l and contact time as 90 min. Adsorbent dose is a significant factor to be considered for effective removal as it determined sorbent-sorbate equilibrium of the system. As dosage of adsorbents increases the removal efficiency of iron increases is shown in fig 2.

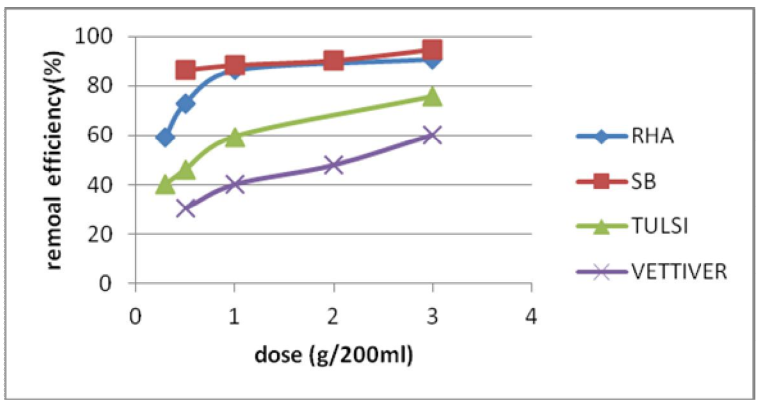

Figure 2:

Influence of initial concentration

The effect of RHA, SB, Tulsi and Vettiver were studied with different initial concentration such as 10 mg/l, 15mg/l, 20mg/l, 25mg/l and 30mg/l with different adsorbent dosage of 0.3, 0.5, 1, 2, 3 and for different time as 30min, 45 min, 60 min, 75 min, and 90min. The fig.3 is plotted by varying concentration with dosage of adsorbents as 0.3 mg/l and contact time as 90 min. It can be seen that the amount of iron adsorbed by the absorbents increases with increase in concentration in fig.3.

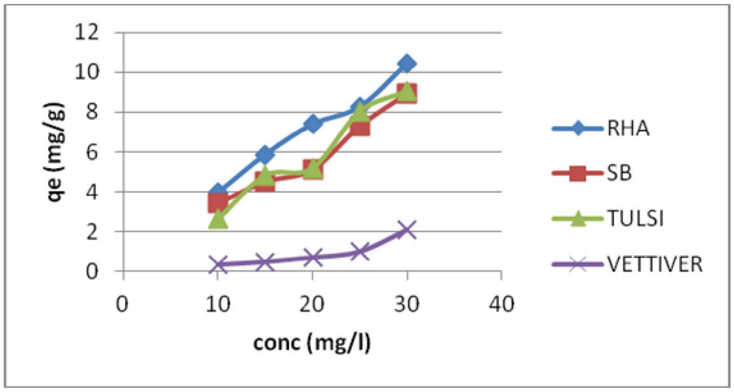

Figure 3:

Multiple Linear Regressions

Multiple linear regression analysis is carried out with removal efficiency of adsorbents as dependent variable and contact time, concentration, dosage as independent variables. It consists of analyzing the correlation of contact time, concentration, dosage for finding removal efficiency of adsorbent.

3. RESULTS AND DISCUSSION

Regression Analysis for Rice Husk Ash

Regression Statistics						
Multiple R	0.898891504					
R Square	0.808005936					
Adjusted R Square	0.801676462					
Standard Error	9.919828464					
Observations	95					
ANOVA						
	df	*SS*	*MS*	*F*	*Significance F*	
Regression	3	37685.68967	12561.9	127.6577	1.69598E-32	
Residual	91	8954.672705	98.403			
Total	94	46640.36237				
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	0.822498182	4.365041178	0.188429	0.85096	-7.8481197	9.493116
Initial Conc.	-0.578631636	0.149861014	-3.86112	0.000211	-0.876312123	-0.28095
Dose	10.08232727	1.015397922	9.929435	3.58E-16	8.065364083	12.09929
Time	0.8004	0.047977333	16.68288	2E-29	0.705098924	0.895701

Regression Analysis for Sugarcane Bagasse

Regression Statistics						
Multiple R	0.953203617					
R Square	0.908597136					
Adjusted R Square	0.905583854					
Standard Error	6.134298099					
Observations	95					
ANOVA						
	df	*SS*	*MS*	*F*	*Significance F*	
Regression	3	34039.4633	11346.48777	301.5308107	3.87561E-47	
Residual	91	3424.294799	37.62961317			
Total	94	37463.7581				
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	-1.41081831	2.792921245	-0.505140742	0.61468121	-6.958613143	4.136976522
Initial Conc.	-0.26893392	0.092373114	-2.911387433	0.004524659	-0.45242176	-0.085446084
Dose	8.37584806	0.681310421	12.29373248	4.8139E-21	7.022508634	9.729187486
Time	0.813232914	0.029668584	27.41057399	9.38002E-46	0.754299918	0.87216591

Regression Analysis for Tulsi Powder

Regression Statistics						
Multiple R	0.919446043					
R Square	0.845381026					
Adjusted R Square	0.840283697					
Standard Error	6.972632349					
Observations	95					
ANOVA						
	df	*SS*	*MS*	*F*	*Significance F*	
Regression	3	24189.37432	8063.125	165.8479	9.13795E-37	
Residual	91	4424.20177	48.6176			
Total	94	28613.57609				
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	-8.68512367	3.068180809	-2.83071	0.005716	-14.7796878	-2.59056
Initial Conc.	0.017112854	0.105337079	0.162458	0.871305	-0.192126308	0.226352
Dose	7.456920801	0.713721656	10.44794	2.97E-17	6.039200441	8.874641
Time	0.662182456	0.033723194	19.63582	1.77E-34	0.595195475	0.729169

Regression Analysis for Vettiver

Regression Statistics						
Multiple R	0.831019645					
R Square	0.69059365					
Adjusted R Square	0.68039344					
Standard Error	11.17394451					
Observations	95					
ANOVA						
	df	*SS*	*MS*	*F*	*Significance F*	
Regression	3	25359.91365	8453.30455	67.7038702	4.22457E-23	
Residual	91	11361.99026	124.8570358			
Total	94	36721.90391				
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	-36.99666135	5.08745198	-7.272139668	1.1959E-10	-47.10225951	-26.8910632
Initial Conc.	0.254722803	0.168262453	1.513842209	0.13353146	-0.079509881	0.58895549
Dose	10.42737557	1.241042531	8.402109767	5.5986E-13	7.962197097	12.8925541
Time	0.606853359	0.054042876	11.2291093	7.1598E-19	0.499503827	0.71420289

R^2 indicates the amount of total variability explained by the regression model. It measures the linear association between removal efficiency of adsorbents (Y) and predictor variables (dose, contact time and concentration.
F-Test can be used to simultaneously check the significance of number of regression co-efficient.
T-test checks the significance of individual regression coefficient. The test is used to check if a linear statistical relationship exists between the response variable (removal efficiency) and predictor variables.

4. CONCLUSION

The equations of the model were arrived for different adsorbents such as rice husk ash, sugarcane bagasse, tulsi powder and vettiver. The equations arrived using multiple linear regression, are as follows

For rice husk ash, $Y= 0.82-0.57X_1+10.08X_2+0.80X_3$
For sugarcane bagasse, $Y= -1.41-0.27X_1+8.38X_2+0.81X_3$
For tulsi powder, $Y= -8.68+0.017X_1+7.46X_2+0.66X_3$
For vettiver, $Y= -36.99+0.25X_1+10.42X_2+0.61X_3$

These equations are used to find the trend and the effect of adsorbents on iron removal. This multiple linear regression model focuses on the strength of the relationship between contact time, concentration and dosage on the percentage of iron removal of adsorbents.

The removal efficiency of rice husk ash is 91.02 % at 90 min contact time, 3 g of dosage and 15 mg/l of concentration. The removal efficiency of sugarcane bagasse is 94.90 % at 90 min contact time, 3 g of dosage and 15 mg/l of concentration. The removal efficiency of tulsi powder is 75.52 % at 90 min contact time, 3 g of dosage and 15 mg/l of concentration. The removal efficiency of vettiver is 74.84 % at 90 min contact time, 2 g of dosage and 30 mg/l of concentration.

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