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Modeling of Fixed Bed Column Adsorption Studies Fluoride by Phoenix Dactylifera (Date Palm) Seeds provide Activated Carbon

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Abstract: The fluoride removal from aqueous solution was investigated utilising Phoenix Dactylifera adsorption in a fixed bed column (Date Palm). The effects of flow rate, bed height, and fluoride concentration at the start were studied. Breakthrough curves were plotted after determining maximum bed capacity, % fluoride elimination, and equilibrium fluoride uptake. With a lower flow velocity and a higher bed height, the percentage of fluoride removed increased. At a flow rate of 5 ml/min, a bed height of 10 cm, and an initial fluoride concentration of 5 ppm, a maximum bed capacity of 6.5 mg was achieved. The Three well-known models were used to fit data from column studies known column models. The Yoon-Nelson model, the Thomas model, and the Adams-Bohart model. The experimental data and theoretical results remained in good accord. The study discovered that activated carbon can be used in a fixed bed column to remove fluoride.

Key words: Fluoride, Activated Carbon(AC), Date Palm Seeds, Models Thomas, Adams-Bohart, and Yoon Nelson, Fixed Bed Column Studies

1. INTRODUCTION

Water is essential for life, but we are still unable to supply everyone with safe, affordable drinking water. For all living things, water is a necessary component of life. Only a small percentage of the population, however, has access to safe drinking water. Others drink varied degrees of polluted water. The issue of supplying safe drinking water is causing widespread anxiety around the world, particularly in developing and developing countries. Because India is a developing country with a large population living in villages with limited infrastructure, a high prevalence of the notion of safe drinking water is inhibited by illiteracy as well as a lack of sanitation and hygiene knowledge. On the other hand, the bulk of the rural population drinks contaminated ground water, which contains a wide spectrum of minerals and salts. An excessive level of fluoride in the water is one of them, and it is damaging to people's health. Fluoride is a toxin that accumulates in the body and is less damaging than arsenic but more lethal than lead. Drinking unclean water on a frequent basis causes dental and skeletal fluorosis, as well as a variety of other health problems include gastrointestinal problems. Because "Fluorosis" is regarded as an incurable disease, the only approach to deal with it is to prevent it. As a result, research into the defluoridation of water using a variability of adsorbents has gotten a lot of attention in recent years. Reverse osmosis, electrodialysis, and ion exchange are all methods for defluoridation. The Nalgonda de-fluoridation procedure developed by NEERI has recently acquired popularity, however it has its own set of drawbacks. A number of adsorbents are used to test de-fluoridation activity. Activated alumina is said to have a in height defluoridation volume.

2. MATERIALS AND METHODS

2.1. Materials

Adsorbent: The fruit of Phoenix Dactylifera (Date Palm) seeds were utilised to make carbon.

2.2. *Preparation of Physical Activated carbon:*

The spores of Phoenix Dactylifera were cleaned and broken into little pieces, then washed in distilled water 8 to 9 times. The powder was previously wilted in a 105°C oven for 24 hours. To avoid powder weight loss, the oven dried powder was compacted in three layers in a small container with no air space between each layer; otherwise, the material would burn rapidly, leaving only ash. The small The container was formerly placed into a larger ampule with the lid of the larger container tightly closed, encircling the little container completely in sand. The setup was then heated at a continuous rate in a muffle furnace until it reached 800°C.After reaching The furnace was set to a temperature of 800°C. allowable to cool for around 10 hours before the ampule was removed. The activated carbon was sieved to a size of 300 microns, packed in polythene bags, and maintained in a dessicator.

2.3. Studies on Fixed Bed Columns

A beaker column was filled with activated carbon (Borosil). The column's inside diameter was 1 cm and its height was 60 cm. An above tank was used to store the fluoride solution to be treated. The solution was designed to flow naturally. The movement rate was measured by control valves at the input and outlet. The effects of flow rate, bed height, and fluoride attentiveness at the start were studied. The column was crammed with AC to a height of 7.5 cm(5.46 gm). m to examine the influence of incoming flow rate. Experiments were 3 distinct flow rates were used: 5 ml/min, 10 ml/min, and 15 ml/min, with a starting fluoride concentration of 5 ppm. The 3 distinct flow rates were used: 5 ml/min, 10 ml/min, and 15 ml/min, with 5 cm (4.5gm), 7.5 cm (5.46 gm), and 10 cm (6.96 gm) to evaluate the influence of bed height (6.96 gm). With the use of a control valve, the inlet flow rate was set to 5 ml/min, and the inlet fluoride concentration was set to 5 ppm. The column was packed with AC to a height of 7.5cm (5.46 gm) and fluoride solution of appropriate attentiveness (5 ppm, 10 ppm, and 15 ppm) was complete to movementdone the column at aamount of 5 ml/min to evaluate the effect of original fluoride attentiveness. The pH of the fluoride solution was kept constant throughout all of the trials. After every 10 minutes, the fluoride solution was collected and the attentiveness of fluoride was evaluated using a UV spectrophotometer. The following equation was used to compute the effluent volume:

$$V_{eff} = Qt_{total}$$

Where Veff is the seepage volume collected in millilitres; Q is the volumetric movementamount in millilitres per minute; and ttotal is the total movement time in minutes. The following equation gives the extreme bed volume for a given flow amount and feed concentration:

$q_{total}=Q\int C_{ad}dt/1000$

Where qtotal is the supreme bed capacity in milligrammes; Q is the inflow movement rate in millilitres per minute; and Cad is the adsorbed fluoride concentration in parts per million. The area below the arch of adsorbed fluoride concentration vs time yields the integral value. The following equation gives the whole amount of fluoride transferred to the column:

$$\%\mathrm{Re}\,moval = \frac{q_{total}}{M_{total}}100$$

Where qtotal is the total quantity of fluoride sent to the column in milligrammes, and $M_{total}$is the total quantity of fluoride sent to the column in milligrammes. The equation for equilibrium fluoride uptake in the column is as follows:

$$q_{eq(xp)} = \frac{q_{total}}{x}$$

Where, $q_{eq(exp)}$ is symmetryfluoride uptake, mg/gm; x is quantity of adsorbent in the column, gm.

2.4. Studies on Fixed Bed Columns Modeling

The results of laboratory research can be used to develop full-scale column operations. Many approaches for evaluating the efficiency and usability of column models for industrial activities have been presented. It is vital to forecast the for the required adsorbate, the break through curve and adsorbent capacity must be determined. a specific set of operating parameters in order to design a column adsorption operation. The models Thomas, Adams-Bohart, and Yoon-Nelson were employed to assess adsorption data from fixed bed column investigations in this study. The mass transmission model posits that fluoride travels from the solution to the particle's coating, then diffuses concluded the fluid film to the surface adsorbent surface. Intraparticle dispersalthen adsorption on the active site follow. The following is the lined form of the Thomas adsorption model:

$$\ln(\frac{C_o}{C_t} - 1) = \frac{K_{TH} q_e x}{Q} - K_{TH} C_o t$$

Where Co is the starting fluoride concentration in parts per million (ppm); Ct is the seepage fluoride attentiveness at time t in parts per million (ppm); K_{TH} is the Thomas model constant in L/min.mg; and qe is the predicted adsorption volume in mg/gm. x is the adsorbent mass in grammes; Q is the inlet streamattentiveness in millilitres per minute. The slope and intercept of a plot of ln (C0/Ct -1) vs t are used to calculate KTH and qe. Adsorption rate is proportional to remaining adsorbent, according to the Adams-Bohart modelattentiveness and adsorbing species concentration.

The first phase of the break through curve is described using this concept. The subsequent equation gives the lined version of the Adams-Bohart model.

$$\ln\left(\frac{C_t}{C_0}\right) = K_{AB}C_0 t - \frac{K_{AB}N_0 Z}{U_0}$$

Where C0 is the original fluoride attentiveness, ppm; Ct is the effluent attentiveness at time t, ppm; Z is the bed depth, cm; N0 is the supreme fluoride uptake volume per unit volume of the adsorbent column, mg/L; U0 is the lined velocity of the influent fluoride solution, cm/min; and KAB is the Adams-Bohart rate constant, L/mg.min The slope and intercept of ln (Ct/Co) vs t are used to get the values of K_{AB} and N0. The Yoon-Nelson model's main goal is to forecast how long a column will run before it needs to be regenerated or replaced. The model provides a straightforward representation of the break through curve. The main benefit of utilising this model is that it does not necessitate any particular information on the type of adsorbent, adsorbate appearances, or the physical assets of the adsorbent bed. The likelihood For each adsorbate molecule, Adsorption occurs at a proportionate rateto the chance According to this model, the amount of adsorbate and the likelihood on the adsorbent of adsorbate breakthrough. This model suggests that, semi of the whole fluoride incoming the adsorbent bed is adsorbed in a fixed bed in a timely manner 2, Where does the time for 50 come from percent break through. The linedmethod of the Yoon-Nelson model is as follows:

$$\ln\left(\frac{C_t}{C_0 - C_t}\right) = K_{YN}t - K_{YN}\tau$$

Ln(C_t/C_O-C_t) = K_{YN}t-k_{YN}τ

Where C0 represents the starting fluoride attentiveness in ppm, Ct represents the fluoride attentiveness at time t in ppm, t represents the flow duration in minutes, and t is the time necessary for 50 percent breakthrough in minutes. The Yoon-Nelson rate constant, KYN, is 1/min. The slope and intercept of ln (Ct/ (C0-Ct)) vs t are used to calculate KYN.

3. RESULTS AND DISCUSSION

3.1. Adsorption and the Inlet Flow Rate

On the break through curve, the following trend was seen when the inlet movement rate was varied from 5 ml/min to 15 ml/min.

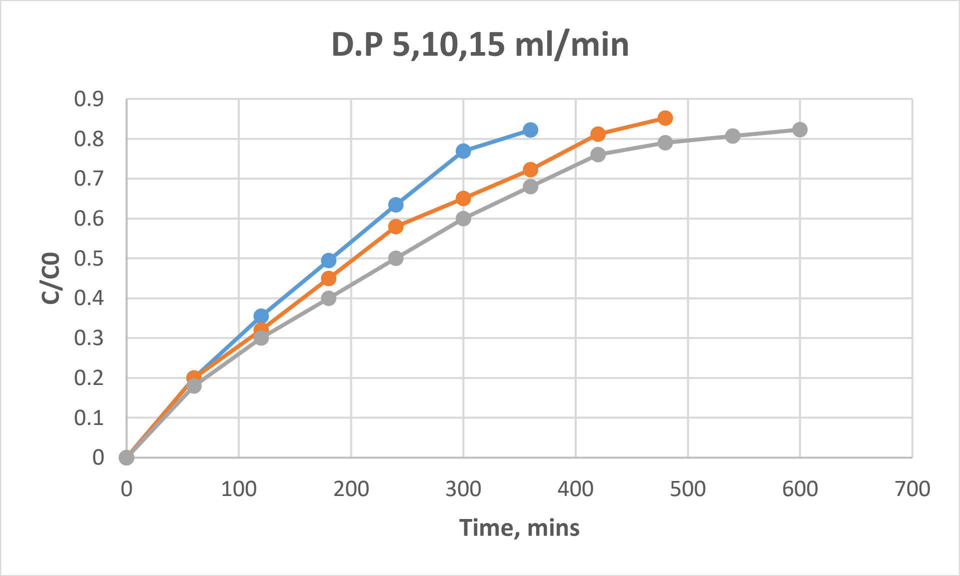

Fig 1: Outcomeon the break through curve of inlet flow rate.

The graph overhead illustrates that increased flow rates resulted in faster break through. The fluoride solution had enough time to adsorb on the adsorbent at the lower flow rate. For both fluoride, higher fluoride removal occurred at lower flow rates. At increasing flow rates, the break through arch became steeper and lifted back to origin. The bed will take longer to become saturated at a higher movement rate. In the table below, the parameters derived from the influence of inlet flow rate are provided. The overall adsorption capacity of the bed, qtotal, dropped as the flow rate increased, as seen in the table above. The residence period of the solute in the bed was shorter at higher flow rates.

Before equilibrium was attained, the solute exited the column. The percentage of fluoride removed reduced When the volume of the flow rose. At lower flow rates, there was more adsorption.

3.2. Adsorption and the Height of the Bed

The following graphic depicts the influence of bed height on adsorption by adjusting the bed height from 5 cm to 10 cm.

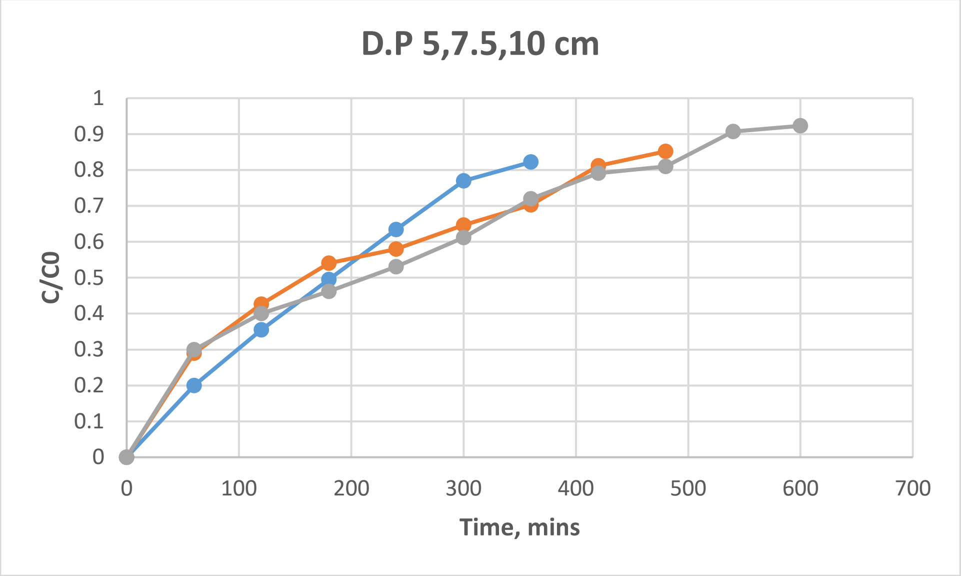

Fig 2: Outcome of bed height on break through curve

Fluoride solution had greater time to contact the adsorbent as the bed height climbed. As a result, more fluoride was removed. As a result, the fluoride concentration in the effluent was reduced. As can be seen in the diagram above, the slant of the innovationarch reduced as bed height increased, resulting in a larger mass handover zone. At lower bed heights, the break through curve was steeper. The table below shows the column characteristics derived from the influence of bed height. The total adsorption volume of the bed rose when the bed height was increased. More adsorption sites were accessible at deeper bed depths, resulting in higher fluoride elimination.

3.3. The Influence of Fluoride Concentration at the Start on Adsorption

The effect of initial fluoride concentration was investigated using three different levels of fluoride: 5 ppm, 10 ppm, and 15 ppm. With an increase in fluoride concentration, the following trend was found.

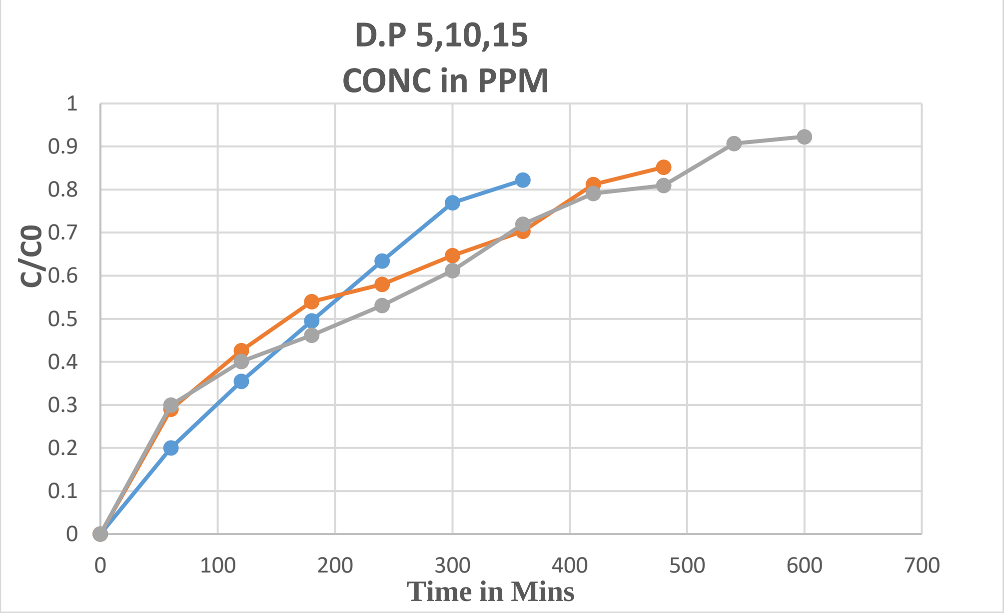

Fig 3: Outcome of initial fluoridefocus on the break through curve

The break through curves are spread at lower fluoride concentrations, as can be shown. Breakthrough curves grew sharper as fluoride concentrations increased. Changes in concentration gradient affect saturation rate and minimise break concluded time, as shown in the graph above. This can be clarified by the fact that as the fluoride concentration rises, more adsorption sites are covered. The break through curve becomes steeper as the fluoride concentration increases. The pushing force for mass transfer will increase as fluoride concentration rises. As a result, the adsorption zone shrank. The table below shows the column characteristics derived from the effect of starting fluoride attentiveness. The adsorption capacity of the bed rose as the starting fluoride concentration increased, as seen in the table above. However, as the attentiveness of fluoride amplified, the percentage of fluoride removed dropped. The Thomas, Adams, and Bohart models, as well as the Yoon-Nelson model, were used examine fixed bed adsorption data.

3.4.1. Model Thomas

Experimental data were trim to equations to obtain the supreme adsorption volumeqe(max) and the kinetic coefficient K_{TH} . The following table summarises the matching model limits calculated from the lined plot (figure not shown).

TABLE 1: Linear Regression Analysis Parameters for the Thomas Model

Q (ml/min)	H (cm)	Co(ppm)	$q_{e(max)}$ (mg/gm)	K_{TH} L/min..mg	$q_{eq(exp)}$ (mg/gm)	r^2
10	5	5	0.40	$2.28x10^{-4}$	0.34	0.984
10	5	10	0.20	$3.9x10^{-4}$	0.30	0.974
10	5	15	0.12	$6.6x10^{-4}$	0.24	0.962
5	5	20	0.10	$4.75x10^{-4}$	0.31	0.992
15	5	5	1.69	$1.0x10^{-4}$	0.40	0.942
10	7.5	5	0.72	$1.0x10^{-4}$	0.80	0.923
10	10	5	0.74	$7.1x10^{-5}$	1.20	0.991

The experimental adsorption capacities obtained using the Thomas model are nearly identical, as seen in the table 1 above. As a result, the experimental data and theoretical results are in good accord. It can be seen that when the flow rate increased, the extreme adsorption capacity and constant K_{TH} both declined. This is due to the fact that the solute's residence duration in the bed was shorter. With an increase in bed height, the value of qe(max) increased, whereas the K_{TH} values declined. This is because there were more reactive sites accessible at greater bed heights. qe(max) increased as fluoride concentration increased, while K_{TH} decreased. This is due to the fact that when my income grows, so does my ability to help others. This is because the driving vigor for adsorption increased as attentiveness increased.

3.4.2. Adams-Bohart model

Table 2 shows the values of the adsorbent's adsorption capacity, N0, and the model's kinetic constant, K_{AB}, as obtained by linear regression analysis. The results reveal that as the flow rate amplified, the adsorption capacity N0 dropped. The related coefficients KAB rose in value. The reduced residence time of the solute in the column causes a decrease in adsorption capacity. The adsorption capacity increased as the bed height increased. K_{AB} values have dropped. The adsorption volume increased as the fluoride concentration increased.

TABLE 2: Constraints of the Adams-Bohart Model Using Linear Regression Analysis

FlowRate(ml/min)	BedHeight(cm)	FluorideConc(ppm)	N0 (mg/gm)	K_{AB} (L/min.mg)	R^2
10	5	5	1.45	$1.21x10^{-4}$	0.91
10	5	10	1.21	$1.50x10^{-4}$	0.97

10	5	15	1.17	1.63x10^{-4}	0.97
5	5	20	1.38	1.23x10^{-4}	0.97
15	5	5	2.76	9.1x10^{-5}	0.98
10	7.5	5	3.21	5.0x10^{-5}	0.98
10	10	5	5.03	2.6x10^{-5}	0.91

3.4.3. Model Yoon-Nelson

The Yoon-Nelson approach was castoff to calculate the time required for a 50% break through. Table 3 summarises the values of and K_{YN} obtained by suitable the investigational data to equation (8).

TABLE 3: Parameters of the Yoon-Nelson Model Using Direct Regression Analysis

FlowRate(ml/min)	BedHeight(cm)	Fluoride Conc(ppm)	τ (min)	K_{YN} (min-1)	R2
10	5	5	133.77	0.0036	0.97
10	5	10	50.52	0.0071	0.96
10	5	15	21.23	0.0132	0.94
5	5	20	27.00	0.0098	0.97
15	5	5	812.68	0.0021	0.98
10	7.5	5	370.00	0.0023	0.98
10	10	5	285.53	0.0027	0.93

The time essential for 50 percent breakdownover reduced as the flow rate amplified, as shown in the above findings. This was attributed to the solute's shorter residence period in the column. The Yoon-Nelson rate continual rose as the flow rate increased for both fluorides. With increasing bed height, The amount of time required to achieve a 50% break through has increased. More adsorption spots were accessible at higher bed depths, and break through time was reduced. The time necessary for 50 percent break through reduced as the initial fluoride concentration amplified. The driving force for adsorption amplified as the fluoride concentration amplified. As a result, it took longer for the bed to become saturated.

4. CONCLUSION

The elimination of fluoride in a secure bed column was examined in this study. The adsorbent remained activated carbon obtained from date palm seeds. The research was accepted out in a fixed bed column with an interior diameter of 1 cm and a length of 60 cm. On the break through curve, the effect of inflow flow rate, bed height, and initial fluoride content was examined. Adsorption was shown to be higher when the flow rate was lower, the bed depth was greater, and the initial fluoride concentration was lower. The Thomas, Adams-Bohart, and Yoon Nelson models were used to model the fixed bed column. The experimental data and theoretical results were in good accord. According to the findings, activated carbon bursting in a column can be employed as an active adsorbent for fluoride removal.

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