IN SITU TREATMENT OF CR^{+3} ONTO ZERO-VALENT IRON FROM WASTEWATER BY PERMEABLE PACKED COLUMN FILTER+

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Abstract

The present study was conducted for Cr^{+3} removal which is one of the most toxic wastewater pollutants onto zero-valent iron. In this system, the toxins are removed from in situ site by an arrival of the wastewater through a permeable sorbent packed columns filter occupied with a special sorbent solid .However, the filter resources should be carefully chosen. A chain of batch tests were handled with synthetic wastewater. The contact time mixing of sorbate and sorbent (0-240) min, initial Cr^{+3} concentration (50-250) mg/L, pH (3-6), zero-valent iron dosage (10-100) g/ L, and achieve the speed of agitation (50-250) rpm, have been studied the effect of these parameters in batch tests and the outcomes displayed that the optimum values for the efficiency of removal of Cr^{+3} (=93%) were 90 min, 50 mg/L,4, 50 g/L and 200 rpm respectively. As well as the results showed that the model Langmuir in representation of adsorption data is the best fitting compared with model of Freundlich under the same circumstances. Mathematical model which is established on ''finite element'' technique was handled to simulate the carrying of Cr^{+3} under equilibrium situation. The data based on predicted and experimental showed that the permeable sorbent filter acting the role of potential in the limitation of the sorbate plume movement and a respectable matching between these data were obtained with RMSE ''root mean squared error'' no more than 0.152.

Keywords*:* Zero-valent iron; Cr^{+3}; Permeable sorbent filter; wastewater; packed column.

المعالجة الموقعية للكروم من المياه الملوثة باستخدام العمود المرشح المعبأ بمادة الحديد الصفر التكافؤ النفاذة.

د. حسنين سعدعبد الزهرة

المستخلص:

هدف هذا البحث هو دراسة ازالة الكروم الذي يعتبر واحدا من اهم الملوثات التي توجد في المياه وذلك باستخدام مادة الحديد الصفر التكافؤ. تم العمل باستخدام منظومة لازالة التسمم من المياه من خلال عمود ماء معبأ بمواد لها القابلية على اختزال هذه الملوثات تم اختيارها بعناية. تم اجراء تجارب الدفعات و دراسة تأثير عدة متغيرات مهمه مثل زمن التماس (٠-٢٤٠) دقيقة، الدالة الحامضية (٣-٦)، كمية الجرعة للمادة المازة (١٠- ١٠٠ غم)/لتر، التركيز الاولي للكروم (٥٠-٢٥٠) ملغم/لتر وسرعة الانفعال الاهتزازي (٥٠-٢٥٠) دورة/دقيقة. اظهرت النتائج ان احسن القيم للحصول على كفاءة الازالة للكروم (=٩٣%) هي ساعة ونصف، ٤، ٥٠ غم/لتر، ٥٠ ملغم/لتر و٢٠٠ دورة/دقيقة. كذلك بينت النتائج بأن موديل لانكمير هو الاحسن في التمثيل لبيانات الامتزاز الملوث مقارنة بموديل فريندلج ولنفس

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الظروف. لتمثيل انتقال الملوثات باتجاه واحد بالطبقة الرملية في وجود وعدم وجود المواد الممتزة تم استخدام طريقة الفروقات المحددة عبر برنامج حاسوب جاهز. وقد اظهرت النتائج التي تم الحصول عليها من البرنامج والنتائج التجريبية ايضا ان هذا المرشح يلعب دورا هاما في ازالة الملوثات.

الكلمات الدالة: الحديد صفر التكافؤ، الكروم، المرشح الممتز النفاذ، المياه الملوثة، العمود المعبأ.

Introduction

Societies are exposed to Cr^{+3} through breathing, eating or drinking and through skin contact with Cr^{+3} or chromium mixes. It can bring about hypersensitive responses, for example, skin rash. Breathing in chromium can bring about nose disturbances and nosebleeds. Other medical issues that are brought on by Cr^{+3} are respiratory issues, debilitated invulnerable frameworks, and change of hereditary material, lung growth and passing **[1]**. The World Health Organization (WHO) has determined that chromium is a human mutagenic and carcinogenic. The maximum admissible concentration specified by the UK Water Supply (Water Quality) is 0.05 mg/L.

In cationic and anionic forms the application of Fe^0 (zero-valent Iron) to eliminate metals has been examined **[2, 3, 4**, **5, 6, 7, 8].** As given in **[9]**, it was concluded that rapid removal of metals in the Fe^0 occurs likely due to the reductive precipitation/coprecipitation and/or because of the sorption on top of the surface of iron ions or/and onto the iron oxidation products. The type of mechanism depends on the type of metal removed, the other accompanying substances and physicochemical situations in the Fe^0 bed.

The main feature of sorbed filter is the submissive nature of the In situ of treatment: the wastewater poignant under the slope hydraulic natural through the region of the response absorbent where the contaminant is sullied or put out of action. This technique has been found to be extra cost-effective than inflate and processing. It has been exhibited capacity to decrease the spread of sorbates which demonstrated troublesome and costly to deal with different strategies for cleaning **[10, 11]**.

The important theoretical and studies of experimental onto Fe^0 and its capacity to remediation of heavy metal ions in wastewater which has been succeeded. "Kinetics" energy of metal particles as of acidic arrangements on rotational particles of iron which have been examined above a huge scope of temperatures, concentrations and agitation velocities **[12]**. The deletion of inorganic and organic contaminants from wastewater by Fe^0 was examined. Mechanisms of removal process were prevalent in lowering inorganic or organic of pollutants in status of Fe^0 and paralysis of mineral pollutants in situation of apatite **[13]**. In continual system the decreasing of chromium ions by slope iron has been examined, using as decreasing factor the next iron (scrap) figure and dimensions: 1. whirlpool fibers, 2. shredding, and 3. fine particles (powder). The figure and dimensions of scuffle iron were originated to have an important impact on chromium ions and iron types' pH in column discharge, concentration, and on chromium ions decreasing mechanism **[14]**. Under dynamic flow conditions a continuous column experiments were carried out in to investigate the productivity of low-price penetrable sorbent filter to eliminate numerous inorganic waste product from acidic wastewater. A weight of scrap iron/sand combination was used (50:50%) as applicant sorbent media so as to make active precipitation, supposing sorption and decrease–corrosion mechanisms **[15]**. The best mass ratio between iron and sand in metal ions deletion from wastewater so as to equilibrium the removal rate (favored by growing Fe^0 gratified) and the conservation of the hydraulic conductivity (preferred by expanding the pumice substance of the mix) was measured **[16]**.There is no effect of the flow speed of wastewater on the sorption act of permeable

sorbente filter, but it does have influence on treating period because metal ions are conveyed quicker from its origin to the permeable sorbent filter with larger wastewater stream speed **[17]**.

The use of Fe^0 is achieved economical goal of the present study by using cheap and more effective material for removing Cr^{+3} from synthetic wastewater in permeable packed column filter which can be used for in situ treatment of Cr^{+3}.

Experimental Labor

1. Materials

In the current study obviously Iraqi soil from Karbala region as areal and In situ soil was used as permeable average for conducted the tests. As determined by the distribution of particle size (ASTM D 422), these soil can classified as sandy soil (SS) where the ratio of sand and silt were 94 and 6 % respectively. The sand permeability, which was examined by a constant head permeameter is 2.00 x 10^{-4} cm/s. 1.75 g/cm^3 and 0.42, respectively were the measured values of the bulk thickness and bed porosity. Pure zero valent iron was prepared from Iron filings that are mostly a byproduct of the grinding, filing, or milling of finished iron products, this sample with effective particle size D10 of 0.5 mm, average particle size D50 of 0.9 mm and Dry density of 2.3 g/cm^3. The idealistic Fe substance of these sorbents are ~92 % with bed porosity 0.6, Fe^0 was pre- cleaned with $CH3)_2CO$, dehydrated and saved in an air free place until utilized. A stock solution were prepared of chromium with a concentration of (1000 mg/L) by using Cr $(NO_3)_3$ (minimum purity 99.5%). A 4.577 g of chromium nitrate were liquefied in distilled water around 0.2 L. It was diluted to 1 L with distilled water after 10 ml concentrated nitric acid was added **[18]**.

2. Batch Tests

The examinations of batch equilibrium were investigate to identify the optimal sorption situations. The differed parameters utilized as a part of these investigations were agitation speed, contact time, initial concentration, pH of the solution and Fe^0 dosage. Arrangement of 250 ml cone shaped jars are working and every jar is loaded with 100 ml of the sorbate solution. A fixed weight of sorbent was loaded into various jars and the blends were shook on a rotating shaker, HV-2 ORBTAL (Germany).A (15 ml) of the sample was taken from each one. The solution of sample was clarified to detach the Fe^0 and a constant volume of the obvious solution was taken for the examination of the amount of metal ion by AAS (atomic absorption spectrophotometer) Buck, Accusys 211 USA. The impact of different parameters like pH (3-6), Fe^0 weight (1, 2, 3, 5 and 10) g, primary Cr^{+3} concentration (50-250) mg/L and agitation rapidity (50-250) rpm were considered in term of their impact on the productivity of evacuation. The amount of Cr^{+3} taken in the Fe^0, q_e (mg/g), has been calculated at this way **[19]**:

$$q_e = (C_o - C_e)\frac{V}{m} \quad (1)$$

Where C_o is the initial chromium ions concentration before blending with Fe^0 in the solution (mg/L), C_e is the equilibrium of chromium ions residual concentration (mg/L), V is the solute volume in the jar (L), and m is the Fe^0 mass (g).

Langmuir and Freundlich (Eqs.2-3) models are utilized to the portrayal of sorption information in this way **[20, 21]**:

$$q_e = \frac{abC_e}{1+bC_e} \quad (2)$$

Where b is the saturation factor (L/mg) and a is experimental factor.

$$q_e = K_F C_e^{1/n} \quad (3)$$

Where: *n* is an empirical coefficient and K_F is a coefficient of Freundlich sorption. *n>1*

3. Continuous Tests

The schematic drawing (Fig. 1) which is demonstrates the reactor system utilized in this study. After the base this system is developed of glass pipe having length70 cm and radius identical to 2.5 cm. The column pipe is prepared by seven examining point at the separation of (10, 20, 30, 40, 50, 60, 65) cm. These points must to be developed of stainless steel appropriate which obstructed by Viton plugs. Examining has been done at settled circumstances as of testing guides utilizing needle be put in the middle of the pipe column.

The column packed entirely with 40 cm profundity of (sandy soil) SS sample was carried out after the bottommost, at the start of every test. At that point, Fe^0 with profundity of 10 cm was set at the top surface of the fixed bed SS and 15 cm of the SS was loaded directly over the Fe^0. The section was loaded by distilled water which was provide gradually into the base of the segment as well as enforced rising above the bed, forceful the air ahead of it. By way of a consequence of execution, there were no hardness faced air with captured. All tests was accomplished at room temperature.

The solution of polluted with Cr^{+3} was presented in the packed column from supply tank organized by pump, flow meter and also three valves. The flow rate values require (5- 20) ml/min.

Observing of Cr^{+3} concentrations along the depth of the column in the sampling points was taken for a time of 12 hours (4, 8 and 12). The four ends of Viton plugs enclosed point 1, point 3, point 5, and point 7 were connected to needles in every exam. As well as determine these places just for sampling, the packed column wastewater streak was sealed and from these points a lesser quantity of aquatic was taken (2-2.5) ml. At this manner, the samples were taken at the flow rate of the packed column to reduce flow problem inside the packed column. The samples were directly presented in poly-ethylene containers and examined in AAS. Incompressible homogeneous, as well as steady after period for porosity of aquatic-filled was presumed to the filling substantial in the section. All system compounds lines consists of an inactive material.

For this system the test of tracer was accomplished to evaluate the coefficient of operational dispersion. The column was packed with a SS in a dehydrated situation for a deepness of 50 cm. For the packed column 1 g of NaCl was dissolved in 1 L distilled water as a tracer solution was continually provided, at the proportion of (5-20) ml/min. When utilized conductivity meter at z_o = 65 cm (point 7) as a concentration descriptive, electrical conductivity was observed with time. For this situation, the value of D_L is given by the accompanying equation **[22]**:

$$D_L = \frac{1}{8}\left[\frac{(z_o - Vt_{0.16})}{(t_{0.16})^{0.5}} - \frac{(z_o - Vt_{0.84})}{(t_{0.84})^{0.5}}\right]^2 \quad (4)$$

Where D_L is the linear of coefficient of dispersion, *V* a means leakage pore velocity (capacity rate of flow / irritated sectional area of voids), the arrival times are $t_{0.16}$ and $t_{0.84}$ of C/C_o = 0.14 and 0.82 comparative mass transfer values, respectively.

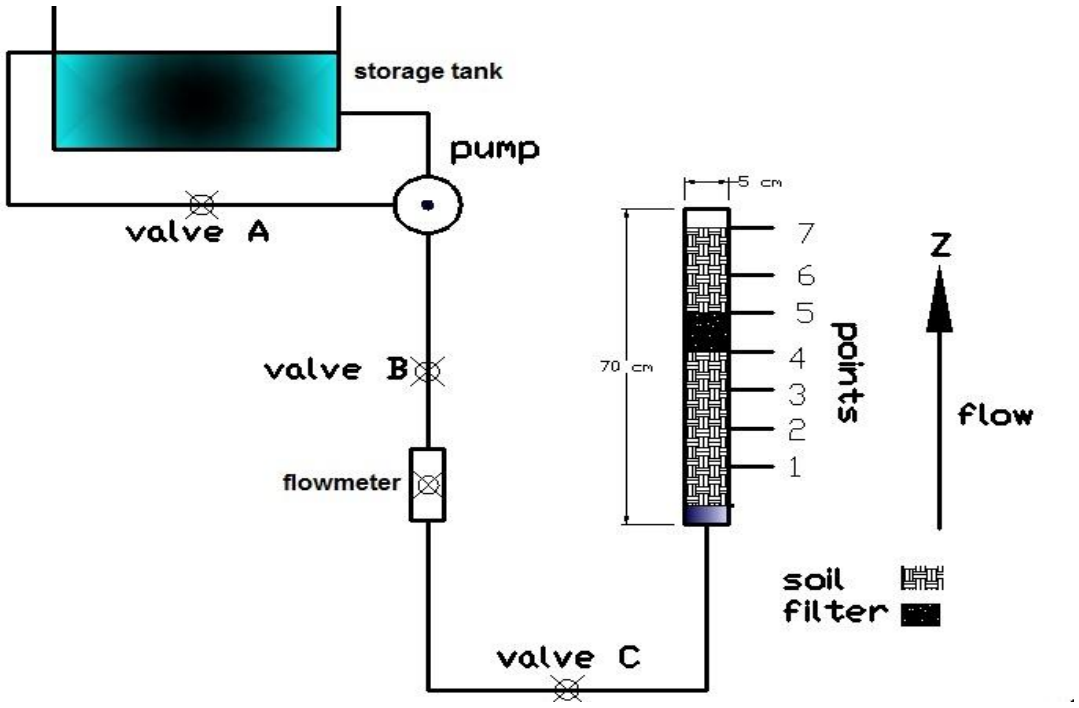

Figure 1: Schematic diagram of continuous experimental (packed column filter)

Results and discussions

1. Examination of sorption factors

1.1 Impact of pH and contact time

The of contact time impact on the removal rate of chromium ions utilizing 50 g of Fe^0 to 1L of Cr^{+3} arrangement in room temperature as shown in Fig.2. The removal rate for diverse values of pH was fast at the start but it slowly reduced through time till it became balance. The schemes are disclose that maximum percentage removal rate of the Cr^{+3} almost after 90 min of contact time. At the start of the process, removal efficiency is higher due to the existence of enormous number of places existing for the sorption methods.

In addition to that(Fig.2) shows the sorption of Cr^{+3} onto the Fe^0 was tested at altered pH ranging from 3 to 6 with C_o=50 mg/L and various contact time values. Sorption attraction is normally controlled by pH at pH_{PZC} ("point of zero charge").

The pH_{PZC} is the pH in which an affirmative charge by protonation existing in almost the same numbers with passive charges produced by the progress of deprotonating onto the iron surface. At pH below pH_{PZC} (acidic condition), protons are sorbed on the "functional group" that reasons the iron particle surface to get a clear affirmative charge and as a result, prevent cation sorption. Under the opposite condition (above pHpzc), the oxygen molecule stays deprotonated and the surface of particle prevails to have a clear passive charge, so, promotion cation sorption **[23]**. In addition that, the maximum rate of percentage removal of Cr^{+3} was succeeded at pH 4 because of pH below pH_{PZC} and protons are sorbed as mention previously.

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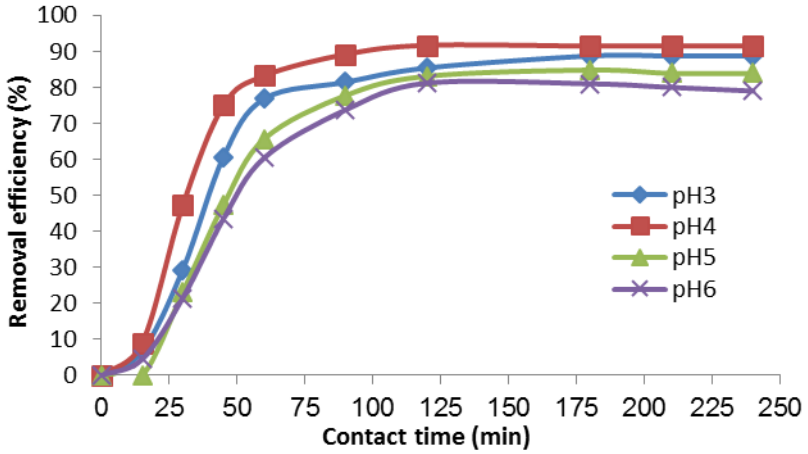


Figure 2: Effect of different pH values on Cr^{+3} Removal efficiency onto Fe^0; C_o = 50 mg/L, 200 rpm and W= 5 g Fe^0/100ml.

1.2. Impact of initial Cr^{+3} concentration

The removal efficiency improved in reverse with the initial Cr^{+3} concentration has been describe in (Fig. 3). It is obvious that the percentage removal rate of Cr^{+3} reduced from 93% to 70% with increment the initial Cr^{+3} concentration as of (50-250)mg/L. This is fullness of the effective places existing on the Fe^0 particles for contact with chromium ions. These consequences show that actively fewer useful places become involved with increment Cr^{+3} concentrations in the solute **[24]**. Removal efficiency was calculated as follows:

$$\%\ Removal\ efficiency = \frac{initial\ concentration - equilibrium\ concentration}{initial\ concentration} * 100 \qquad (5)$$

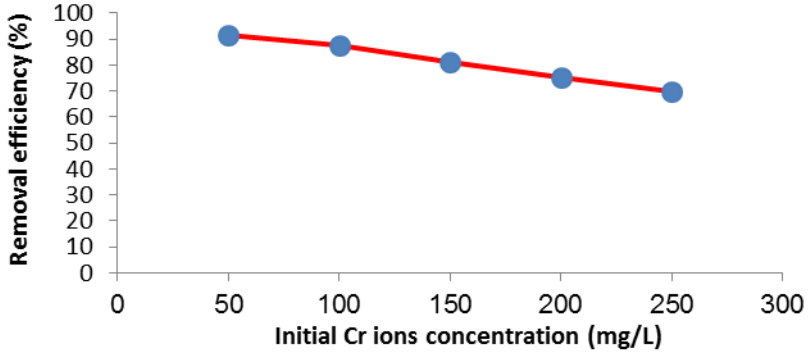


Figure 3: Removal efficiency with variation of initial concentration, of Cr^{+3} onto Fe^0 (pH=4; dose=5/100 g/ml; contact time=90 min and agitation speed= 200 rpm).

1.3. Impact of dosage

Fig. 4 explain that the requirement of Cr^{+3} sorption onto Fe^0 dose was considered by loading the quantity of Fe^0 (10 to 100) g / L of Cr^{+3} solution. It could be remarked that rate of deletion advanced with increment Fe^0 amount (10 – 50) g/L at a constant initial Cr^{+3} concentration. It was because of the way that the higher measurements of Fe^0 in the solution, the higher accessibility of sorption places. That indicates that a lot of Fe^0 particles can offer more iron surface- effective places to impact with chromium atoms for speed up Cr^{+3} removal rate **[25]**.

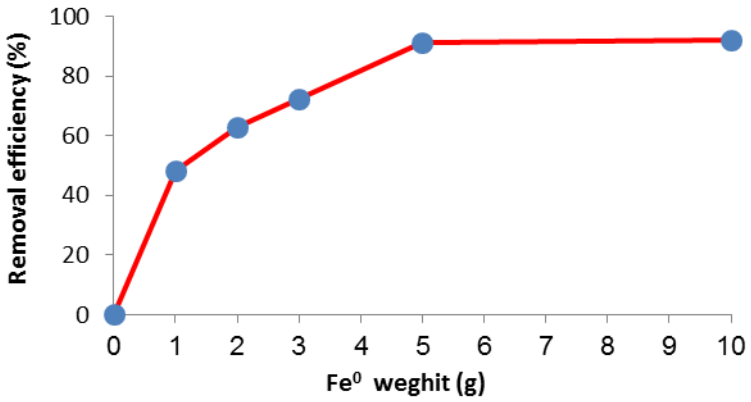


Figure 4: Removal efficiency of Cr^{+3} with difference of Fe^0 dosage, (pH=4; C_o=50 mg/L; contact time =90 min and agitation speed 200 rpm).

1.4. Impact of agitation speed

Agitation speed impact on the percentage removal of Cr^{+3} was considered by changing the rapidity of agitation from 50 to 250 rpm with save other optimum limitations which got in the prior stages. The Cr^{+3} uptake rise with the increase of agitating speed (Fig. 5). There was progressive increment in Cr^{+3} take-up when agitating rate was expanded (50 – 200) rpm which around 93% of Cr^{+3} have excluded. The consequences are too found that agitating with 200 rpm is enough to confirm that totally the surface binding places are made freely existing for Cr^{+3} sorption. Consequences showed that above 200 rpm there is not any or little important variation in Cr^{+3} elimination. These outcomes can be related to the way that the expansion in the agitation rate enhances the distribution of Cr^{+3} towards the Fe^0 surface. So, good contact is achieved between Cr^{+3} and the binding places, which supports active spread of Cr^{+3} to the Fe^0 binding places.

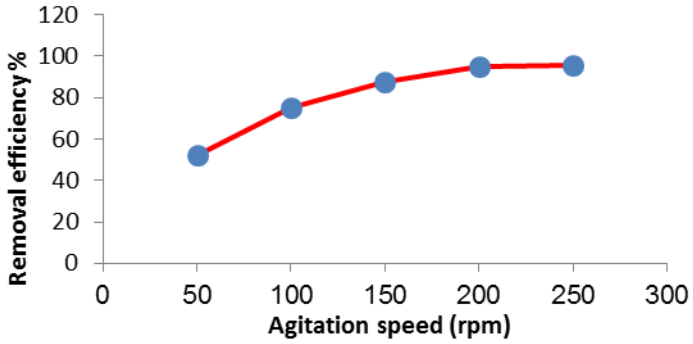


Figure 5: Efficiency of removal of Cr^{+3} with variation agitation speed (C_o=50 mg/L; contact time= 90 min; pH= 4; Fe^0 dose =5 g/100 ml).

1.5. Impact of the isotherms sorption parameters

The sorption isotherms were created via plotting the capacity of Cr^{+3} expelled from the mixture solute qe (mg/g) vs. the equilibrium concentration of Cr^{+3} Ce (mg/L) at fixed temperature [**26,27,28].** The data of the batch exams for Cr^{+3} where connected with Langmuir and Freundlich models. The parameters for every model obtained from nonlinear statistical fit of the equation to the experimental data (STATISTICA software, version 6). The equations of these models will be;

$$q_e = \frac{0.119C_e}{1+0.056C_e} \qquad R^2=0.9936 \qquad (6)$$

$$q_e = 1.85C_e^{0.0396} \qquad R^2= 0.8659 \qquad (7)$$

These models are delivered the top image of chromium ions sorption onto Fe^0 sorbent. Besides that, the model of Langmuir has been chosen to describe Cr^{+3} sorption solute onto sorbent in the PDE "partial difference equation" ruled the conveyance of a mixture go during balance sorption during penetrable sorbative filter in the continual system.

2. Longitudinal dispersal coefficient for SS and Fe^0

Consequences of the investigational data concerned the calculation of D_L (longitudinal dispersion coefficient) at V (diverse values of velocity) for Fe^0 and SS are used as a linear correlation in this way:

For Fe^0, $D_L = 12.8x + 2$ R^2=0.9942 (8)

To SS, $D_L = 4.1406x - 6.765$ R^2=0.9763 (9)

Eqs. (8- 9) are used the overall shape of longitudinal hydrodynamic dispersion coefficient as shown below:

$$D_L = D_{mech} + D^* \quad (10)$$

Where D^* and D_{mech} are and active molecular diffusion coefficient and the mechanical dispersion coefficient respectively.

3. Theoretic mathematical model

The solute (dimensional) conveyance in the soaked bed of SS which famous advection-dispersion equation and displayed like this:

$$D_z \frac{\partial^2 C_{cr}}{\partial z^2} - V_z \frac{\partial C_{cr}}{\partial z} = R \frac{\partial C_{cr}}{\partial t} \quad (11)$$

Where R is recognized as the retardation factor then it has the consequence of delaying the passage of sorbed kinds comparative to the advection obverse. It will be assumed equivalent to 1 for wastewater flow through the sandy soil, which is realistic for this kind of soils. Alternatively, the solute sorption onto Fe^0 filter is directed by Langmuir model isotherm and R is stated as follows:

$$R = 1 + \frac{\rho_d}{n_B}\left(\frac{0.119}{(1+0.056C_{rB})^2}\right) \quad (12)$$

Where n_B is the filter porosity. Eq. 11 can be used for SS bed into the sections where $0 \leq z \leq 0.4$ m and $0.5\ m \leq z \leq 0.65$ m to exist theoretic proof for column experiment described previously. A similar condition can be connected for Fe^0 filter in the section where $0.4\ m \leq z \leq 0.5$ m. Nevertheless, constants and parameters associate to the Fe^0 and SS filter in addition to initials and boundaries condition embraced here for this confirmation are stated in Table 1.

An evident technique within finite variation techniques was practical to the PDE describing the conveyance of sorbent through soaked bed of the Fe^0 and sandy soil filter. The formula was expressed with the subsequent creator: time, onward variance was utilized; for space, retrograde variance was utilized for modest partial difference; and center difference was utilized for quadratic partial difference. PC package transcribed in MATLAB R2010b sotware (rendition 7.11) was established to apply the model depicted previously. Likewise, a similar model was resolved by utilizing the (COMSOL Multiphysics 3.5a) programming which depends on finite element technique.

The concentration streaks of Cr^{+3} in the bed without attendance of permeable sorbent filter at altered values of wastewater flow rate after many interval periods as repoints in Fig. 6. These

concentrations are considered from mathematical techniques defined overhead and they are compared with analytical result set by:

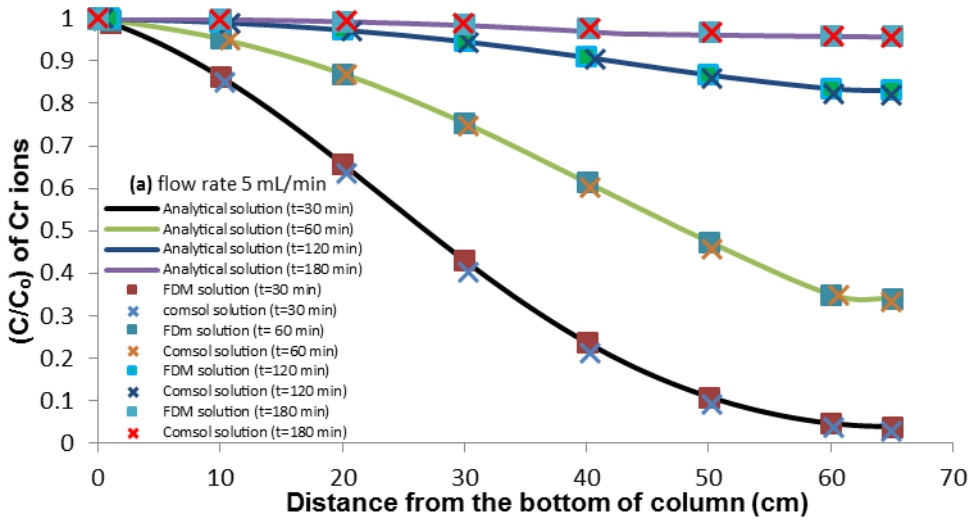
$$C(z,t) = \frac{C_o}{2}\left\{\text{erfc}\left(\frac{z-V_z t}{\sqrt{4D_z t}}\right) + \exp\left(\frac{zV_z}{D_z}\right)\text{erfc}\left(\frac{z+V_z t}{\sqrt{4D_z t}}\right)\right\} \quad (13)$$

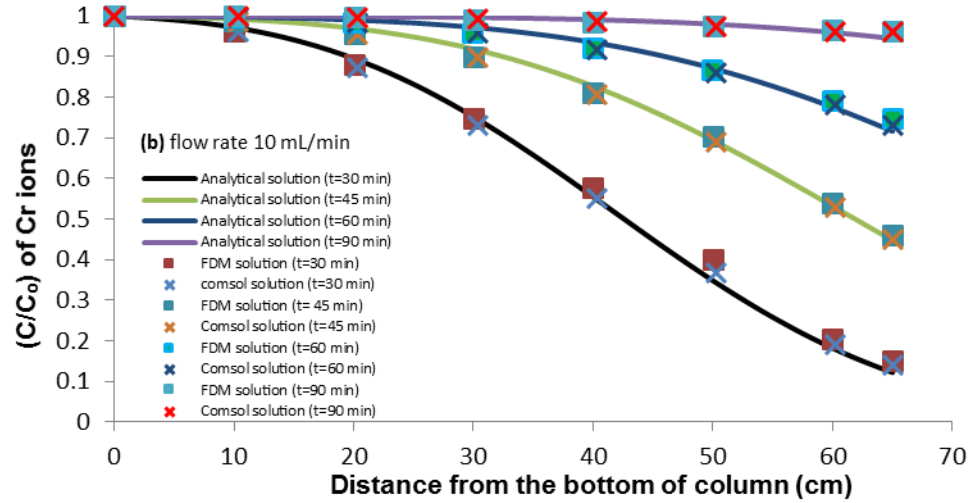
Where erfc ( ) is "complimentary error function". There is a well matching between numerical and analytical solutions and shows that the numerical solution methodology is illustrative of Fe^0 spreading in saturated SS. Figure 6 displays that the spread of polluted plume is so quick and the element of period is necessary for success the regularized solute concentration (C/C_o) = 1 at the exit of packed column was no more than 360 min. Moreover, it looks that the increment flow rate value will rise the speed of movement for similar cross section zone of SS sample and, thus, this will increment the sorbent plume spread velocity.

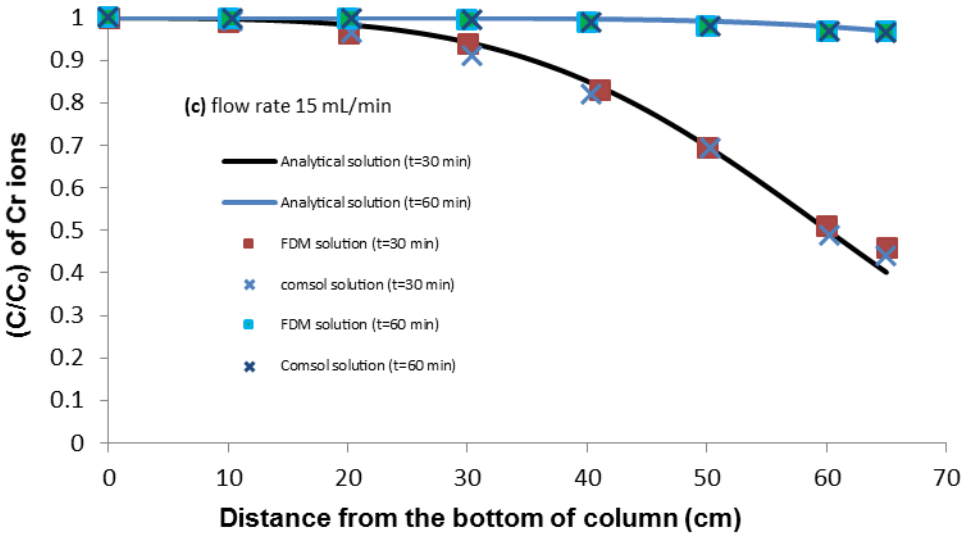
The expected Cr^{+3} concentrations in the numerical solutions for diverse flow rate values after the starter of the permeable sorbent filter display that the sorbent plume is held up in the Fe^0 filter and the Cr^{+3} concentration success the exit of the column is nearby zero as shown in Fig. 7 and in contrast with Fig. 6 the significant part of filter in constraint the spread of sorbent plume. However, it is expected that filter working will reduction with time because the lessening of *R*. Fig. (7) shows that a comparison between the prediction of curves by applying (theoretical model) and experimental consequences with RMSE (root mean squared error) no more than 0.152, that means the greatest fitting was obtained when applying the mass transfer correlations presented by model.

Table 1. Related modeling constants, measured parameters, and conditions used of Cr^{+3} transport in one dimension column.

Item	Parameter	Value
Soil bed characteristics	Depth of soil bed after filter (cm)	15
	Depth of soil bed before filter (cm)	40
	Soil bed porosity (n_A)	0.42
	Longitudinal dispersivity of soil bed (αL, cm)	4.14
	Bulk density of soil bed (g/cm^3)	1.75
	Density of particle (g/cm^3)	2.65
Fe^0 characteristics	Depth of filter bed (cm)	10
	Filter Porosity (nB)	0.6
	Longitudinal dispersivity of filter (α_L, cm)	12.8
	Bulk density of filter (g/cm^3)	2.3
Initial condition	Concentration of Cr^{+3} (mg/L)	0
	Concentration of Cr^{+3} @ z = 0 (mg/L)	50
Boundary conditions	Advective flow ($\frac{\partial c}{\partial z}$) z = 65 cm	0


(a) flow rate 5 mL/min
Analytical solution (t=30 min)
Analytical solution (t=60 min)
Analytical solution (t=120 min)
Analytical solution (t=180 min)
FDM solution (t=30 min)
comsol solution (t=30 min)
FDm solution (t= 60 min)
Comsol solution (t=60 min)
FDM solution (t=120 min)
Comsol solution (t=120 min)
FDM solution (t=180 min)
Comsol solution (t=180 min)
(C/C0) of Cr ions
Distance from the bottom of column (cm)


(b) flow rate 10 mL/min
Analytical solution (t=30 min)
Analytical solution (t=45 min)
Analytical solution (t=60 min)
Analytical solution (t=90 min)
FDM solution (t=30 min)
comsol solution (t=30 min)
FDM solution (t= 45 min)
Comsol solution (t=45 min)
FDM solution (t=60 min)
Comsol solution (t=60 min)
FDM solution (t=90 min)
Comsol solution (t=90 min)
(C/C0) of Cr ions
Distance from the bottom of column (cm)


(c) flow rate 15 mL/min
Analytical solution (t=30 min)
Analytical solution (t=60 min)
FDM solution (t=30 min)
comsol solution (t=30 min)
FDM solution (t=60 min)
Comsol solution (t=60 min)
(C/C0) of Cr ions
Distance from the bottom of column (cm)

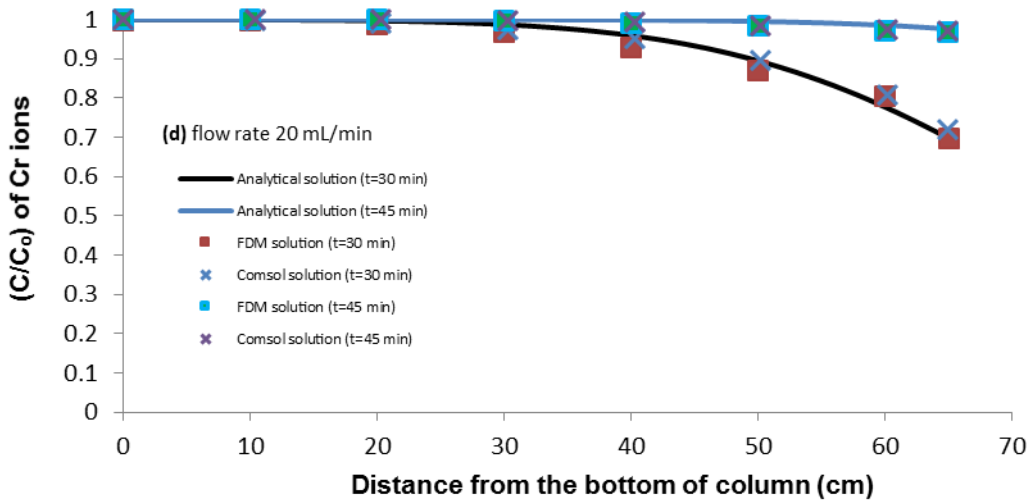
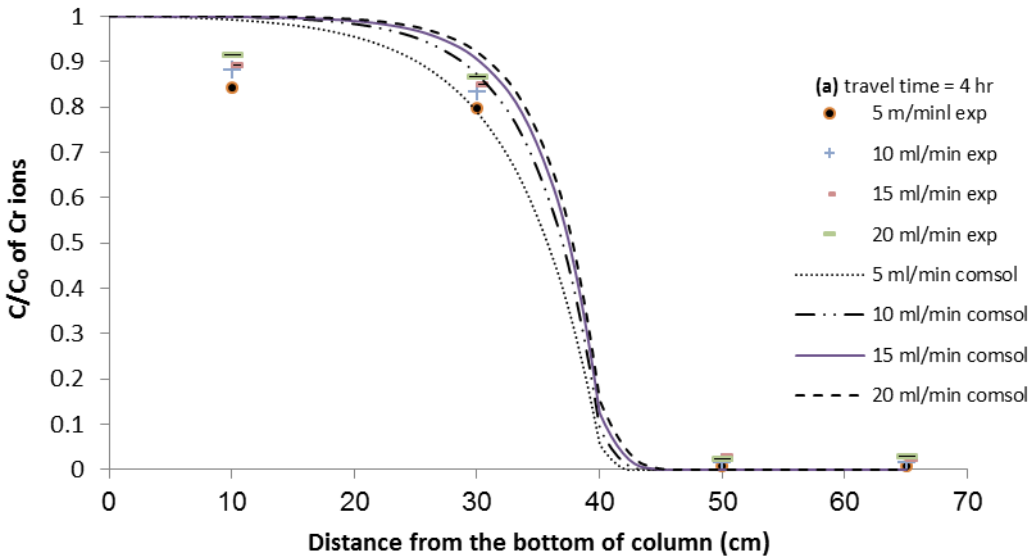


Figure 6: Comparison of conventional solute conveyance along the span of the soil column without utilizing permeable packed filter at diverse time periods between analytical and numerical solutions for rate of flow identical to: a- 5 cm^3/min, b- 10 cm^3/min, c- 15 cm^3/min, d- 20 cm^3/min.



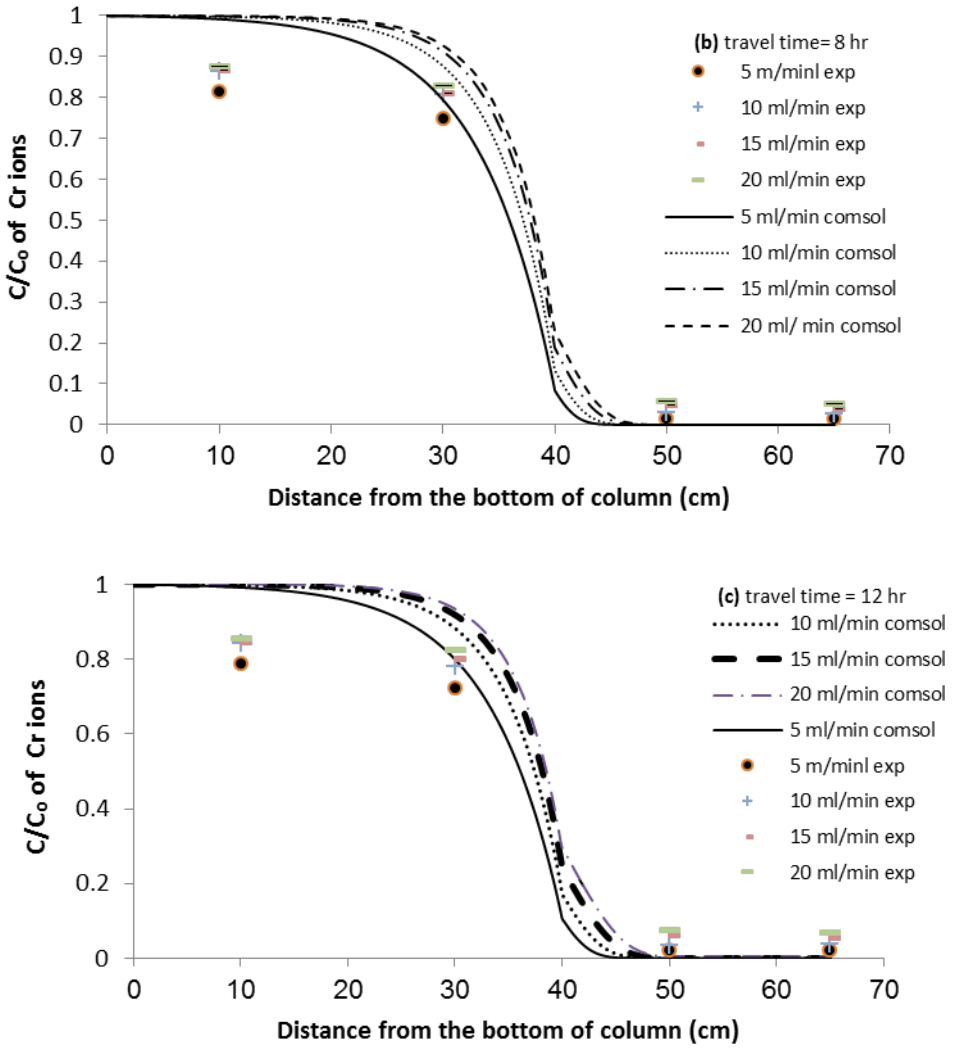


Figure 7. Experimental results and COMSOL predicted curves of Cr^{+3} mass transfer in wastewater for values of transportable time.

The Conclusions

This study revealed the following conclusions, concerning the batch and continuous sorption process. It can be concluded that optimum pH , contact time, agitation speed, initial Cr^{+3} concentration, and dosage were 4 ,90 min , 200 rpm ,50 mg/L, and 5 g/100 ml respectively , that will accomplish the maximum efficiency of removal of Cr^{+3} (=93%) onto Fe^0 sorbent filter. The Langmuir model gives the best fit for the experimental data for Cr^{+3} recognized by high value of (R^2). It has been used successfully to describe equilibrium sorption. However, Langmuir model coefficient was used in the solute transport model through the permeable packed column filter., solved by COMSOL software and explicit finite difference technique beneath balance situation, is the solution of one dimension mathematical model to describe Cr^{+3} conveyance within wastewater and the Cr^{+3} sorption onto the permeable packed column filter. The consequences showed that the Fe^0 filter is effective system in the limitation of sorbent plume. The data of experimental of Cr^{+3} were fitted well the theoretical data that obtained by applying mass transfer correlation equations developed by these models.

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