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Research Article

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Biosorption as a Perfect Technique for Purification of Wastewater Contaminated with Ammonia

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Abstract

Eichhornia Crassipes root powder (ECRP) has been used to remove ammonia from aqueous solutions. The biosorption factors such as biosorbent dosage, pH, initial ammonia concentration, and contact time have been considered in batch conditions. The optimal conditions, at pH (6), sorbent dose 5 g/l, time (30 min) ammonia concentration (10 mg/l). Langmuir is better suited than Freundlich isotherm. The kinetic models: Thomas, Yoon-Nelson, and Bohart-Adm were applied. These models showed that; the adsorption capacity decreased with flow rate increases as follows: (32.57, 31.82, 31.25, and 30.17 mg/gm) respectively at a flow rate (10, 15, 20, and 25 ml/min). The roots powder of Eichhornia Crassipes was used to treat specific drainage wastewater obtained from the Sabal drain at Menoufia, Egypt. The average efficiency of ammonia removal was 87% per batch adsorption method at pH value = 7.5, sorbent dose 5 g/L, uptake period (30 minutes), and primary load 7.1 mg/l; however, ammonia removal by column continuous adsorption method exceeded 94 %. In addition, (ECRP) has been shown to be efficient in removing arsenic, sulfate,

nitrates, nitrite, silica, iron, manganese, copper, zinc, aluminum, and lead from actual sewage wastewater, in addition to removing more than 75 % COD.

Keywords: Biosorption Process; Waste Management Process; Batch Adsorption Study; Wastewater Effluents; Modeling Accuracy.

1. Introduction

Water contamination is among the most urgent concerns of the moment. Nitrogen compounds are a major freshwater contaminant. Nitrogen contaminants such as synthetic nitrogen, ammonia, nitrite and nitrates, soluble ammonia (NH_3), and positively charged ammonium ions (NH_4^+) occur in wastewater. Harmony in the aqueous interface between two sources of ammonia however according to the reversible reaction:

$$NH_3 \leftrightarrow NH_4^+ \tag{1}$$

When the solution's pH is less than 9.3, ammonia that is bound to hydrogen ions will yield ammonium ions to be dominant (Adeva et al, 2012). Total ammonia nitrogen (TAN) in aqueous solution equivalent to NH_3 and NH_4^+ summation. The ingestion of high concentration ammonia causes severe and chronic effects on human health including eyes; nose, mouth, skin inflammation, burns, reduces insulin sensitivity, causing the blue baby syndrome, permanent blindness, and lung or death (Sadegh et al, 2014; Sprynsky et al, 2005; Knobeloch et al, 2000). High concentrations of NH_3 and NH_4^+ in water supplies increased the need for oxygen and caused disruption to marine life, which is harmful to fish with very small concentrations of around 0.2 mg/l. Ammonia is toxic to all vertebrates that induce epilepsy, coma, and cell death in the central nervous system; cell death in the central nervous system caused by redistribution of potassium

(K^+) with elevated NH_4^+ concentration that threatens to depolarize neurons (Randall and Tsui, 2002; Ip et al, 2001; Sprynskyy et al, 2005). Many technologies have been used to remove ammonia from wastewater, such as chemical, biological, and adsorption. Nitrification (by aerobic bacteria) / Denitrification (by anaerobic bacteria) is a biological mechanism for extracting ammonia from urban and industrial wastewater, but at higher concentrations of ammonia, the cycle is impaired due to the toxic effect of ammonia on nitrifying bacteria (Ismail et al., 2018; Fawzy et al., 2018; Abdelfattah 2018; Ibrahim et al., 2016a; Abdelfattah et al., 2016b; El-Shafai et al., 2016; El-Awady et al., 2015; Randall and Tsui, 2002; El-Shamy et al, 2018). Uranbileg Daalkhaijav (2012) announced 70 % elimination of nitrification/denitrification ammonia from wastewater (Uranbileg and Daalkhaijav 2012; Ip et al., 2001). Reza et al., (2014) recorded nitrification / denitrification removal efficiency of ammonia at various concentrations 25, 40, 80, 120 and 160 mg/l are 87 %, 89 %, 72 %, 66 % and 62 % (Reza et al, 2014; Ryer, 1991). Some experiments have used algae to remove elevated ammonia concentrations from wastewater. The Scenedesmus sp. black algae Has been able to absorb ammonia effectively in concentrations up to 100 mg/l. Halfhide et al., used ammonia reduction microalgae, with 65 % elimination (Halfhide et al, 2015; Gregory et al, 2016; El-Shamy et al, 2017a; El-Shamy et al, 2017b). The ozone molecule's direct oxidation of ammonia is relatively sluggish and produces nitrate, which hence does not remove absolute nitrogen. Xianping Luo et al., (2015) announced ozonation elimination of 85 % of ammonia (Xianping Luo et al, 2015; Uranbileg and Daalkhaijav 2012). Zong et al., (2017) recorded 28.5 % ozonation extraction of total nitrogen (Zong et al, 2017; Reza et al, 2010). An ion exchange mechanism is the fusion of liquid phase ions of equal charge with electrostatically bound ions to an insoluble layer of resin.

$$B^{-} + A \leftrightarrow B + A^{-} \qquad (2)$$

Malovanyy et al., (2013) recorded 88% elimination of zeolite-based ammonium ions (Malovanyy et al, 2013; Park et al, 2010). Malekian et al., (2011) reported the elimination of ammonium ions by natural Iranian zeolite by 91.5 % (Malekian et al, 2011; Halfhide et al, 2015). Saltali et al, (2007) recorded (75-83 %) ammonium ions removal using Natural Turkish Zeolite (Saltali et al, 2007; Xianping et al, 2015). Adsorption is an efficient and cost-effective system for eliminating ammonium ions, versatility in nature, in many cases high-quality treated effluent, and adsorbents may be regenerated by an acceptable desorption cycle. Biosorption has been used in recent years as a natural adsorbent with higher performance, low cost, quality, and fast application in the removal of ammonia from the atmosphere (Zongwei et al, 2017; Malovanyy et al, 2013; Malekian et al, 2011; Saltalý et al, 2007; Kang et al, 2004). Biosorption of ammonium ions from aqueous solutions is a very promising method for eliminating pollutants from the ammonium ions. Table (1) is a compilation of literature on the elimination of ammonium ions by adsorption process. In this study, Eichhornia Crassipes roots powder (ECRP) from Eichhornia Crassipes (water hyacinth) was used to remove ammonia from synthetic and real wastewater collected from Sabal drain at Menoufia, Egypt, using adsorption methods for batch and column. A concentration of ammonia ranged between 5.4 mg/l to 8.2 mg/ in the Sabal drain. The main source of this pollutant is the municipal wastewater discharged through septic tanks in the surrounding villages, although the permissible discharging limits to the Nile water less than 0.5 mg/l.

2. Materials and Method

2.1. Materials:

Ammonia stack solutions were prepared by dilution of ammonia solution 25% prepared by Sigma Aldrich. pH ideals of prepared contaminated water were accustomed for the chosen number using

(1 M) of hydrochloric acid and (1 M) of sodium hydroxide Real drainage wastewater samples were collected from Sabal drain at Menoufia, Egypt**.**

2.2. Equipment

The suspension solutions were shaken by Lab shaker, Wiseshake, SHO-2D, South Korea. WTW-inolab, Germany, ECRP. The obtained imageries were carried out by (SEM). The pictures at diverse amplifications applying Quanta-250 FEG, USA. The absorption spectra of FTIR or the ECLP were documented between 400-4000 ranges applying Jasco-FTIR-Spectroscopy, Japan. The concentrations of ammonia were measured using American Standard Methods (APHA, 2017).

2.3. Preparation of the Bio-Sorbent

Eichhornia Crassipes (Water hyacinth) was collected from the Rosetta branch of the Nile River at the governorate of Menoufia, Egypt. The clean biosorbent is dried in an oven at 80 ˚C for 12 h. the dried form is crushed in a laboratory mill, then sieved to a similar particle size. The biosorbent washed again with deionized water and the decolorization process is subjected by washing with HCl and then NaOH. The decolored form is washed again by deionization water and then dried at 80 ˚C for 1 d.

2.4. Methodology

Intended for batch method, freshly prepared solutions of ammonia with known initial concentration were used for biosorption experiments. Various bio sorbent doses were immersed in 100 ml of the synthetic contaminant solution. The experiments were stirred employing a lab shaker with 250 rpm for 5–60 min. Whatman qualitative No. 4, filter paper used to separate bio sorbents from the solutions. The parameters of untreated and treated wastewaters have been investigated corresponding toward techniques of the American Standard Methods (APHA, 2017).

3. Results and Discussions

3.1. Biosorbent Investigation

3.1.1. Scanning Electron Microscope for Biosorbent

The superficial expanse of the biosorbent was evaluated by using a scanning electron microscope. Fig. 1a showed the particle size of ECRP about (729.6 nm – 2.77 μm) and Fig. 1b showed the pore size at the exterior of ECRP particles about (435.9 nm – 2.67 μm). Fig. 1a,b correspondingly revealed the used particle size and as well as the dispersal of spongy composition alongside the outward of their ECRP before treatment.

3.1.2. FTIR Spectra of Biosorbent

Fig. 2a,b displays the Fourier Transform Infra-Red (FTIR) spectrum of ECRP before and after treatment. The FTIR was applied to attain data about the possible adsorbent - ammonia interactions. The FTIR bands of the unloaded and the ammonia loaded biosorbent in the assortment of 400- 4000 cm-1. The broad and strong peaks at 3853.08, 3744 and 3438 cm-1 represent OH stretching vibrations, while the peak observed at 2923 and 2855 cm-1 showed the asymmetric C-H aliphatic group. The strong peak at 1638 cm-1 was appointed to C=C extending, while the obtained peak at 1542 represents N-H bending. While the gained peak at 1457 and 1427 could be present in the C-H bending. The gotten peak at 1027 cm-1 and 1163 assigned C-O stretching vibrations. The observed peaks at 623 and 435 showed C-X stretching (X= Cl, Br, F, or I). It was notified that most of these functional group capabilities to adsorb ammonia very well from the spectra, the strength of ammonia loaded ECRP was slightly different than the spectra of ECRP before adsorption and there were some shifts in wave numbers after adsorption.

3.2. Batch Adsorption Experiments

In this section, some parameters which effect on the process of adsorption will be studied as follow:

3.2.1. Effect of Sorbent Dose

The consequence of ECLP amount on the elimination of NH_3 was carried at varying doses (0.5, 1, 2, 3, 4, and 5 g/l) at pH (7.4), initial concentration (10 mg/l), shaking speed (250 rpm), and connection time (60 minutes). Fig. 3a showed ammonia exclusion % improved with the growing of ECRP dosage. Fig. 3b demonstrated the ammonia exclusion diminished through growing ECRP dose that ascribed to the saturation of the active sites. Biosorption capacity declined with snowballing biosorbent dose for two reasons. First, with increasing biosorbent dose, aggregation of biosorbent particles leads to a decline in an entire superficial expanse of the biosorbent and an upsurge in dispersion path length. Furthermore, the growth in the dose of biosorbent at a steady concentration of ammonia and solution quantity will have an advantage to unsaturated the active sites throughout the uptake procedure (Wahab et al, 2010).

3.2.2. Consequence of Interaction Period

The outcome of the connection period was studied at (5, 10, 20, 30, 40, 50, and 60 minutes) on the removal percentage of NH_3 by ECRP at pH (7.2), the dose of biosorbent (5 g/l), flow (250 rpm) and original concentration of ammonia (10 mg/l), the outcomes are publicized in Fig. 4 The proportion of elimination of NH_3 was speedy in the initial 10 min, but then develop gradually till achieving balance. The removal percentage at equipoise, was 67% within (30) minute. High ammonia removal was adsorbed in the first 10 minutes probably due to film diffusion on the external surface of the biosorbent when all adsorbent sites were vacant, and the gradient of the solute concentration was high (Halim et al, 2011).

3.2.3. Effect of pH

Effect of pH was studied at (3, 4, 5, 6, 7, 8, and 9) on the elimination of NH_3 at a specific dose (5g/l), preliminary ammonia concentration (10 mg/l), shaking speed (250 rpm), and interaction period (60 minutes). In addition, the solution pH has a significant impact on the uptake of NH_3. Fig. 5 displayed the extreme removal of ammonia was at pH (6). Previous studies stated that; the optimal pH for ammonia removal was at pH (5–6); the properties of ammoniacal solution explain the result; the existence of two types, NH_3 (basic) and ammonium ions, NH_4^+ (acidic) (Azreen et al, 2016; Liu et al, 2016; Buasria et al, 2012). Ammonia removal at low pH is high due to the cation exchange mechanism in an aqueous solution. However, ammonia removal decreases at pH < 5 because of H^+ competition.

3.2.4. Effect of Original Concentration of Ammonia (C_0):

The behavior of ammonia uptake by ECRP was supported by using different initial ammonia concentrations (3, 4, 6, 8, and 10 mg/l) at optimum pH (6), interaction period (30 minutes), dosage (5 g/l), and flow (250 rpm). Fig. 6a shows the removal% of ammonia declines with the increase in its primary load, whilst along with growing loads of ammonia, the compulsory spots turn out to be extra rapidly drenched as the expanse of biosorbent concentration remained constant (Sari and Tuzen, 2009). Fig. 6b shows ammonia uptake increases with the increase in its initial concentration.

3.2.5. Adsorption Isotherm

The adsorption isothermal equation defined the relationship between the aqueous phase concentration of the solute and the sum of the adsorbed solvent. The isotherms of adsorption are measured to identify the adsorption process (Sari and Tuzen, 2009). The Freundlich and Langmuir isothermal equations of adsorption have been used effectively in numerous processes of adsorption (Aksu and Yener, 2001; Ozkaya, 2006; Aktas and Cecen, 2007; Khoufi et al, 2008; Almaraz et al, 2003; Langmuir, 1916).

3.2.5.1. Model of Langmuir Isotherm

This formula is predicated on the presumption that the maximal uptake correlates to a dense monolayer species of adsorbate on the surface of the adsorbent. The adsorption strength is unchanged due to the technological breakthroughs of adsorbents into the surface plane (Kiran et al, 2006).

This formula is defined as:

$$q_e = \frac{q_{max} \; * K_l \, C_e}{1 + K_l \, C_e} \tag{3}$$

Linearized form is:

$$\frac{C_e}{q_e} = \frac{1}{q_m \, K_l} + \frac{1}{q_m} * C_e \tag{4}$$

From equation (5)

$$Slope = \frac{1}{q_m} \tag{5}$$

$$Intercept = \frac{1}{q_m \, K_l} \tag{6}$$

Where q_m and K_L are constants related to Langmuir respectively to the capability of adsorption and its energetic yield, C_e (mg/l) is concerned with the balance load and q_e (mg/gm) is the adsorption measurements at equilibrium.

Langmuir dimensional less separation constant factor or balanced factors, R_L, which is specified by the subsequent formula:

$$R_L = \frac{1}{1 + K_L * \; C_0} \tag{7}$$

From the rate of R_L can be considered and evaluated via the above expression, the physical meaning of the adsorption process to be any disadvantageous when (R_L>1), straight at what time (R_L=1), satisfactory while (0<R_L< 1) and irreparable what (R_L=0). The R_L-assessments for the procedure of adsorption of NH_3 with ECRP have magnitudes amongst 0 and 1, implying the procedure of adsorption is favorable and a high value of K_L was given away to be a function of strong bonding between ammonia and biomass (Ahmad and Rahman, 2011; Gorgulu and Celik, 2013; Meitei and Prasad, 2013; Abdelfattah et al, 2016a; Abdelfattah et al, 2016b). The plotting of Ce/qe alongside Ce is revealed in Fig. 7. Removal of NH_3 on ECRP yielded a straight-talking line. Constants of Langmuir isotherm and their correlation coefficients R^2 are exposed in Table (2).

3.2.5.2. Freundlich Isotherm Model

Among the most popular technical explanations for isothermal adsorption is the Freundlich isotherm that offers an articulation concerning the conglomeration of the surface and the exponential dissemination of effective positions and their forces. The isotherm at Freundlich is described as:

$$q_e = C_e^{\frac{1}{n}} \qquad (8)$$

And in linearized form is:

$$ln\, q_e = ln\, K_F + (\frac{1}{n})\, ln\, C_e \qquad (9)$$

$$Slope = \frac{1}{n} \qquad (10)$$

$$Intercept = lin\, K_F \qquad (11)$$

Where qe (mg/g) is the adsorption capacity at equilibrium, C_e (mg/l) is the ammonia load at equilibrium, K_F is a temperature-related constant and n is adsorption constant for the approach.

The plotting of (ln q_e) versus (ln C_e) is given away in Fig. 8. The uptake of NH_3 onto ECRP a straight line is provided which extinguishable for the standards of Freundlich constant (n) amongst 2 and 10 showed a decent removal capacity (Abdelfattah et al, 2016b; Freundlich, 1906). The constants of Freundlich isotherm and their correlation coefficients R^2 are exposed in Table (3).

3.3. Continuous Column Experiments

The research uses a bursting bed column made of polypropylene with an inner diameter of 5 cm, a height of 100 cm, and its overall volume (1.96 liters). The column has glass beads with a diameter of 1.5 mm were positioned at the top to achieve a height of 2 cm, and a 0.5 mm stainless sieve supported by glass beads were given at the bottom to support the packaging. A known quantity (200 gm) of particle-sized Eichhornia Crassipes (Water Hyacinth) powder (2.4 µm-55.7 µm) was placed in the column to yield sorbent bed height (80 cm) and volume (1.57 liter). A peristaltic pump had fed upward ammonia solutions of initial concentration 10 mg/l at pH (7.3) to obtain desirable flow rates inside the column. Ammonia concentrations of the sewage at the column exit collected at different time intervals were analyzed and the column system was operated till the effluent ammonia concentration reached equilibrium. From the results, at the beginning of contact between ammonia solution and biosorbent on the column, ammonia removal is high, then gradually decline, then rises until it reaches equilibrium (Abdul Halim et al, 2013). Fig. 9 showed the structure of the adsorption column.

3.3.1. Flow Rate Consequence

The study of flow rate effect on adsorption becomes an important factor (Zhao et al, 1999). In this work the sorption capacity of Eichhornia Crassipes powder is studied for various flow rates in the assortment of 10, 15, 20, and 25 ml/min for the original concentration of ammonia 10 mg/l and divan elevation of 80 cm. Fig. 10 represents ammonia removal % against time for the rates of flow

5, 10 and 20 ml/min. Table (4) showed ammonia removal % decreased by increasing the flow rate; The removal efficiency at steady state was 86%, 79%, 75 %, and 70% for the rates of flow 10, 15, 20, and 25 ml/min respectively. Fig. 10 showed an increase in decreasing of the flow rate through ammonia removal. The reduction in ammonia removal at higher flow rates is outstanding to the decreasing of retention time for the solute to interact with the biosorbent and the restricted diffusion of particles into the adsorptive spots or holes of the biomass (Sivaprakash et al, 2010). From the results, it was found the rate of flow of 10 ml/min is the best in the elimination process. The important feature in the design of fixed-bed adsorption column is the rate of flow curve for the effluent and mathematical models to fit them; are mathematical models were applied in this study for the evaluation of column efficiency for the adsorption process (Thomas, 1944; Yoon and Nelson, 1984; Bohart and Adam, 1920).

3.4. Adsorption Models in Continuous

3.4.1. Thomas's Model

Thomas's paradigm is the simple and generally utilized paradigms reported by many researchers (Sarioglu, 2005; Aksu and Gonen, 2003; Yan and Viraraghavan, 2001). Thomas model was adapted from the kinetics of the first-order reaction of adsorption model which is expressed in linear form equation as:

$$Ln\ [(C_0/C_e) - 1] = \left(\frac{M\ Q_{max}\ K_{Th}}{F}\right) - (K_{Th}C_0\ )t \qquad (12)$$

Where k_{Th} is the Thomas model constant (L/mg.hr), Qmax the maximum uptake of solute (mg/g) and t the time (minutes), M mass of biosorbent, and F the flow rate ml/min. C_0 is the initial concentration of ammonia and C_e is the concentration of ammonia in effluent solution. A conspiracy of Ln [(C_0 /C)-1] against t for a given flow rate of 10, 15, 20, 25 ml/min can be applied to calculate the model constants. Figs (11, 12, 13, 14) show the linear nature of the model yielding a virtuous fitting for the investigational results at all flow rates with high correlation coefficients (R^2). The limitations of the Thomas model evaluated at the four rates of flow were reported in Table (5) which showed adsorption capacity diminished with growing flow rate.

3.4.2. Yoon and Nelson's Model

This pattern estimates the possible decrease of the rate of adsorption which is directly proportional to its adsorption action; this model can be articulated as the following equation:

$$ln(\frac{Ce}{C_0 - C_e} = K_{YN} * t - (t_{0.5} * K_{YN}) \tag{13}$$

Where C_0 (mg/l) is initial load, C_e (mg/l) is the load at time t, k_{YN} (1/min) is the rate constant of velocity, and t0.5 (min) is the revolution band for 50% of ammonia being adsorbed by adsorbent Figs (15-18).

3.4.3. Bohart-Adam Model

The Bohart-Adam model shows the adsorption rate is directly proportional to the adsorbent power and concentration used. The equation to the model is defined below:

$$ln\left({}^{C_t}/_{C_e}\right) = K_{AB}C_e t - K_{AB}N_0 {}^{Z}/_{F} \tag{14}$$

Where C_0 (mg/l) is primary load, C_e (mg/l) is the load at time t, K_{AB} (L/mg min) is constant of Borat-Adam kinetic, N_o (mg/l) is capacity load, Z (cm) stands for divan penetration and F (cm/min) is obtained by distributing the rectilinear speed of the rate flow with an expanse of the column see Figs (19-22) and Table (6).

3.5. Regeneration

The efficiency of biosorbent for ammonia removal decreases when it is applied for a long period, mainly because biosorbent gets saturated with NH_3. So, it should be redeveloped previously reusing. Regeneration of NH_4^+-sorbent is a significant step in wastewater treatment for reuse of biosorbent and decrease treatment cost. Two categories of renewal were reported by the researcher; chemical and biological regeneration, in our research, chemical regeneration will be covered in detail. Chemical regeneration is supported by using acid (e.g., HCl, H_2SO_4) or alkali (e.g., NaOH with NaCl or $CaCl_2$) chemicals. Chemical regeneration was reported in several studies (Cyrus and Reddy, 2011; Bolan et al, 2003; Ji et al., 2007; Siljeg et al., 2010). The most used rejuvenation compounds are NaCl and HCl. In NaCl regeneration process, Na^+ ion is exchanged with NH_4^+ ion which loaded on biosorbents; Similarly, in HCl regeneration, H^+ ions are exchanged with NH_4^+ ions which loaded on biosorbents as exposed in the subsequent equivalences:

$$NaCl + Sorbent\text{-}NH_4^+ \rightarrow NH_4Cl + Na\text{-} Sorbent \tag{15}$$

$$HCl + Sorbent\text{ -}NH_4^+ \rightarrow NH_4Cl + H\text{-} Sorbent \tag{16}$$

In this study, five loading and four rejuvenation sequences were carried out. *Eichhornia Crassipes* powder (ECP) loaded with ammonia was regenerated with 60 gm/l of NaCl medium at pH (12) with flow rate (10 ml/min). Ammonium ions (NH_4^+) replaced by Na^+ ions then it converts to NH_3 at high pH according to the next equations:

$$NaCl + ECP\text{-}NH_4^+ \rightarrow NH_4Cl + Na\text{-}ECP \tag{17}$$

$$NH_4Cl + {}^-OH \rightarrow NH_3 + {}^-Cl + H_2O \tag{18}$$

ECP was washed with distilled water and dried at 80 ºC to limit the loss in weight after five cycles; loss of weight was 15%. Elution efficiency (E) is considered from the following equation:

$$E\,(\%) = (M_d / M_{biosorbent}) \times 100 \tag{19}$$

Where, M_d (mg) is the mass of ammonia desorbed which was designed from the elimination result (*C* (mg/l) Vs time/min). Fig. (23) showed NH_3 removal % increased after the first regeneration due to Na^+ ions have activated ECP by converting it ionic Na^+ forms. When the regeneration cycle was repeated, NH_3 removal % slightly decreased in a subsequent adsorption process. Fig. (24) showed high regeneration (desorption) efficiency of ammonia with NaCl medium at pH (12).

3.6. Case Study

The collected wastewater from the Sabal drain was subjected to a complete analysis rendering to the standard method as publicized in Table (7), the dealing with of the collected wastewater utilizing the basin in addition to column methods was achieved and the results illustrated in Table (7 and 8).

3.6.1. Wastewater Treatment Plant

Fig. 25 showed a simple construction of the basin treatment plant for adsorption method, its shelf life is ten years, and it can treat 240 m3/day of polluted water, the plant consists of 2 basins with volume 30 m3 (its dimensions 4x 3x 2.5). Table (9) shows the affordable assessment for the building of the treatment factory. Table (10) shows the low-cost evaluation for the operating cost of the treatment plant. According to our previous study, the construction and consecutively expenses of the treatment can be premeditated proved that it is a low fee treatment, in comparison with the preceding studies, one study utilizing membrane technologies, calculated a sum of 1.67 USD/m3 of the total cost, other researchers calculated the price of 1.974 $/m3, they utilize the electro-oxidation reactor, our study presented a total cost ranged between 0.43 and 0.51 USD/m^3 (Ahmad and Rahman, 2011). For the treatment of Sabal drain water by adsorption column, stainless steel column with depth (5 m), diameter (2.8 m), its total volume (30.77 m^3), and side area (43.96 m2) will be used with a flow rate of 0.5 m^3/min (30 m3/hour), which can treat about 240 m^3/day, this column needs about 4000 kg of ECP (16.6 kg ECP/m^3), the density of ECP 133.3 gm/l. Sabal drains discharge about 48000 m^3/ day to the Rossetti branch of the Nile River, to treatment this quantity of water, we need 200 columns with volume (30.77 m^3). From Tables (10, 11), treatment cost by basin adsorption method about 6.5 L. E/m^3; while treatment cost by column adsorption method (Table 11 and 12) about 10.5 L. E/m^3, so the batch adsorption is the best method (El-Kashef et al, 2019; Shehata et al, 2019).

Conclusion

- Low-cost adsorbent, Eichhornia Crassipes roots powder (ECRP) was used for removing ammonia from synthetic and real drainage wastewater effluents.
- The batch method was employed for studying the behavior of some effective and restricted factors as pH; immersion period, dosage, and an original load of ammonia were premeditated at temperature 25±2 °C. Removal % of ammonia increases with growing the dosage of adsorbent, while the capacity of adsorption (q_e) decline with growing up the dosage of the adsorbent. The optimal pH related to the extreme removal of ammonia was pH (6).
- Ammonia was stacked on the adsorbent awfully rapid through the initial 10 min, although equilibrium was achieved through 30 minutes. The maximum adsorption was 79% at optimum condition, initial concentration (10 mg/l), pH (6), interaction period (30 min), and ECRP dose (5 g/l).
- Langmuir constant (R_L) magnitudes amongst (0 and 1) mean that the adsorptions are satisfactory, and a high value of K_L indicated strong bonding between ammonia and ECRP.
- Freundlich isotherm showed the removal of NH_3 by ECRP yielded a line of straight away. The standards of Freundlich constant (n) amongst (2 and 10) mean a decent outcome.

- The (R^2) in Langmuir isotherm was advanced than Freundlich isotherm for ammonia adsorption, so Langmuir isotherm is better fitted to the experimental data.
- Adsorption column was studied for removing ammonia from prepared wastewater; the flow rate consequence on the progression as; adsorption capacity declined with snowballing of flow rate.
- Thomas model yielding a respectable fitting for the column investigational results at all flow rates with high (R^2) values, the parameters of the Thomas model showed adsorption capacity decreased with increasing flow rate as (32.57, 31.82, 31.25 and 30.17 mg/gm) at a rate of flow (10, 15, 20 and 25 ml/min) respectively.
- Yoon and Nelson model showed t 0.5 increased with the increase of flow rate, which was 29.8, 31.2, 42.8, 64.2 min at a rate of flow 10, 15, 20, 25 ml/min respectively.
- Bohrat-Adam model showed saturation concentration increased with increasing the rate of flow which were 4.2, 6.2, 6.3, 9.1 mg/l at a flow rate of 10, 15, 20, 25 ml/min respectively.
- The loaded powder of Eichhornia Crassipes with ammonia was regenerated for five cycles with NaCl at pH (12). NH_3 removal increased after the first regeneration due to the replacement of NH_4^+ by Na^+, when the cycle was repeated, NH_3 removal slightly decreased in a subsequent adsorption process, NH_3 removal at a steady-state was (83, 87, 86.5, 86, and 85%) for cycles (0, 1, 2, 3, 4) respectively.
- The adsorption technologies was applied to real drainage wastewater, Sabal drainage wastewater; removal of contaminants by batch adsorption method were COD (75.2%), BOD (57%), total dissolved solids (TDS) 97.9, chloride 95.4%, sulphate 82.8%, ammonia 87%, nitrates (NO_3) 94.7, nitrite (NO_2) 93%, phosphate 12.5%, silica 20%, iron 42%,

manganese 60.8%, copper 23%, zinc 20%, free chlorine 7.1%, aluminum 30% and lead 50% ; while pollutants removing by column method were COD (80.3%), BOD (65%) total dissolved solids (TDS) 98.5, chloride 96.5%, sulphate (83.5%), ammonia 94.1%, nitrates (NO_3) 95.1, nitrite (NO_2) 96.6%, phosphate 66.6%, silica 47.3%, iron 58.3%, manganese 54.5%, copper 30%, zinc 50%, free chlorine 25%, aluminum 50% and lead 60%.

Ethical approval

This article does not contain any studies with human participants or animals performed by any of the authors.

Consent to Participate

Done

Consent to Publish

Done

Authors Contributions

All authors contributed to the study's conception and design. Material preparation, data collection, and analysis were performed by Ibrahim Abdelfattah, Fathy A. El-Saied, and Ali A. Almedolab. Writing and revision were provided by Ibrahim Abdelfattah, and A. M. El-Shamy and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

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Competing Interests

The authors declare that they have no competing interests

Data availability

The datasets used and/or analyzed during the current study are available and exist in this manuscript.

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Figures

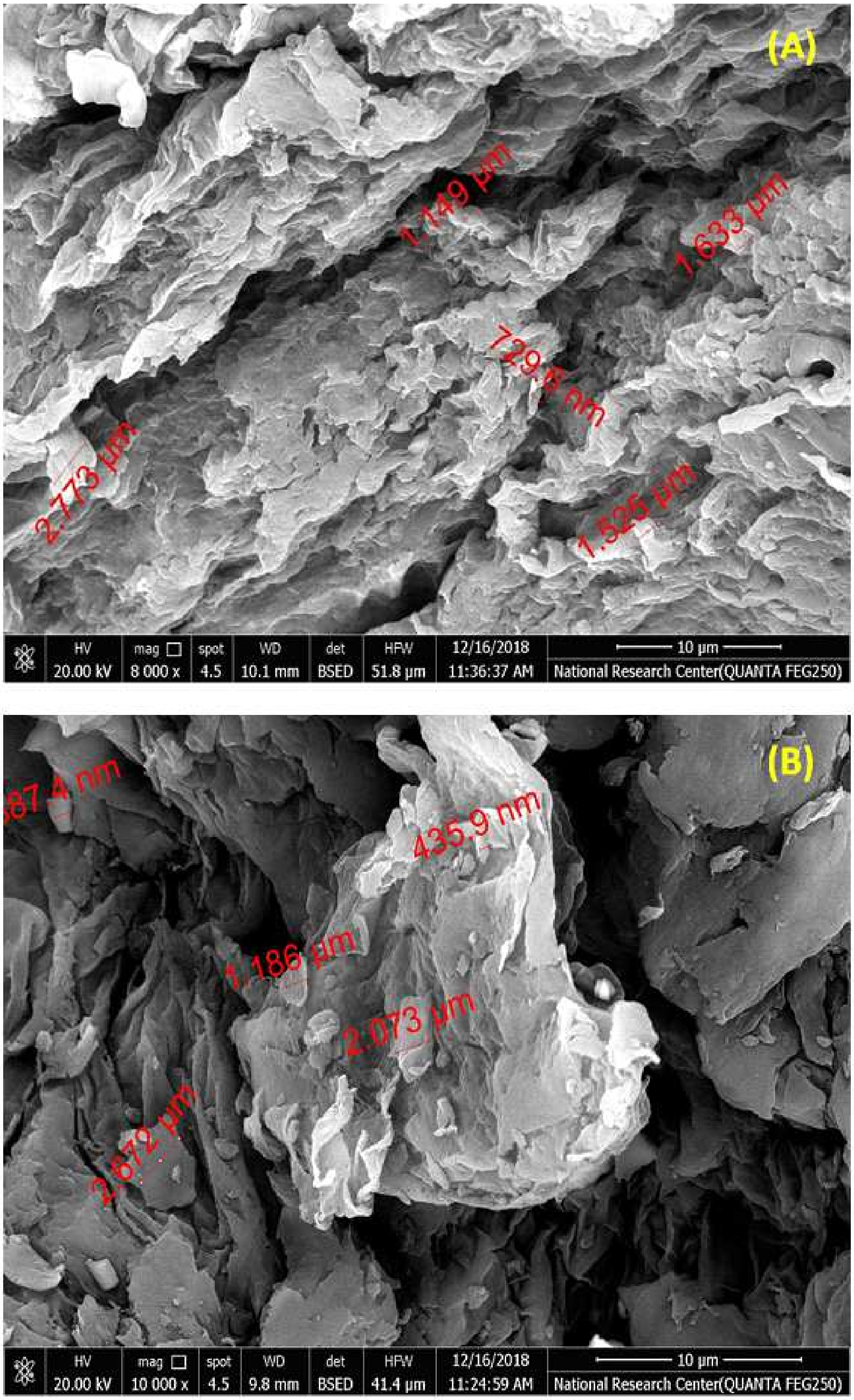
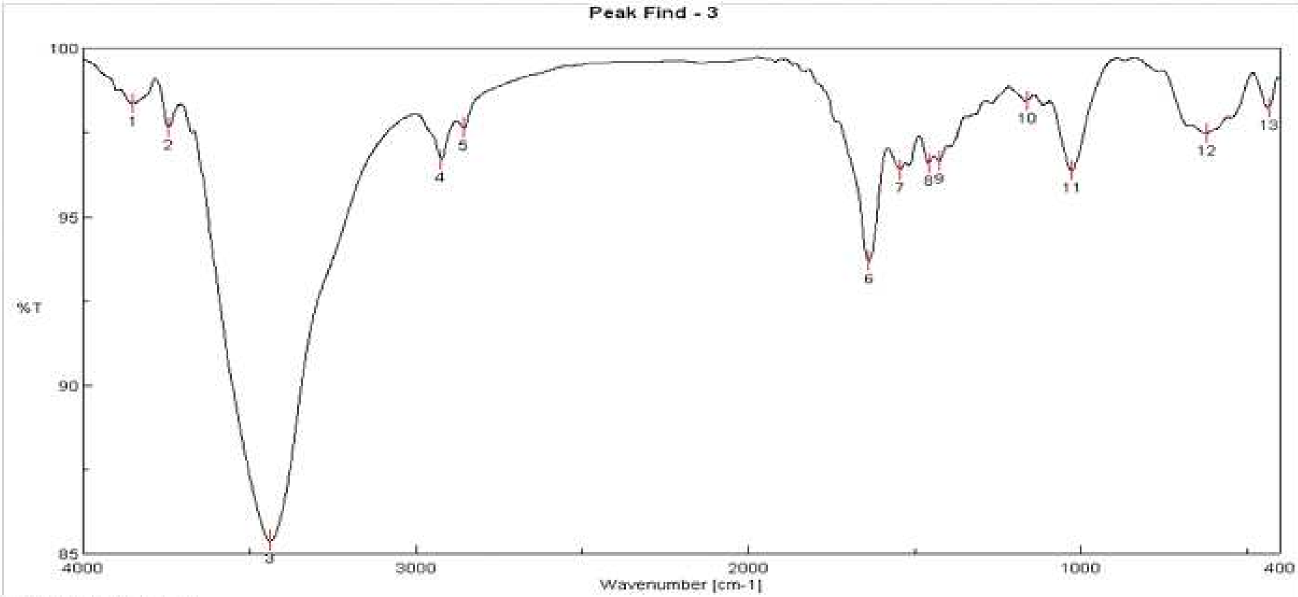


Figure 1

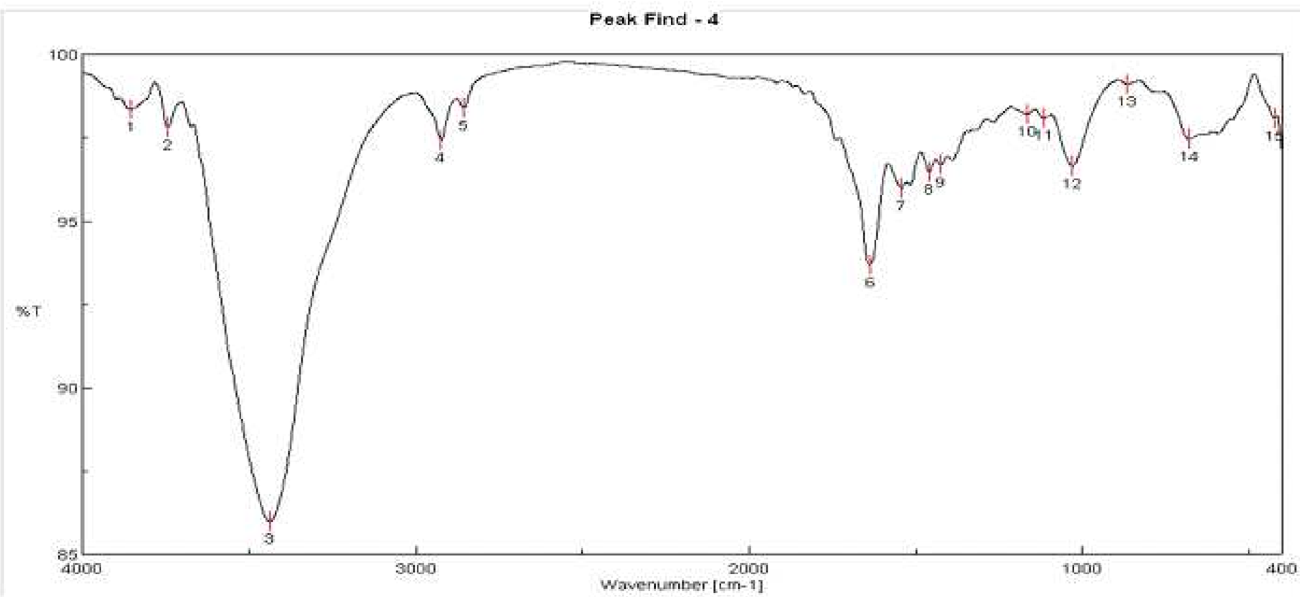
(A) showed the particle size of ECRP and (B) showed the pore size at the surface of ECRP



[Result of Peak Picking]

No.	Position	Intensity	No.	Position	Intensity	No.	Position	Intensity	No.	Position	Intensity
1	3853.08	98.34611	2	3744.12	97.65587	3	3438.46	85.38371	4	2923.56	96.69108
5	2855.1	97.63451	6	1638.23	93.68578	7	1542.77	96.38976	8	1457.92	96.57380
9	1427.07	96.65399	10	1163.83	98.43950	11	1027.87	96.37672	12	623.859	97.48035
13	435.834	98.23404									

(A)



[Result of Peak Picking]

No.	Position	Intensity	No.	Position	Intensity	No.	Position	Intensity	No.	Position	Intensity
1	3854.04	98.34588	2	3745.08	97.80367	3	3438.46	85.98498	4	2923.56	97.42433
5	2855.1	98.39041	6	1637.27	93.67042	7	1542.77	95.97878	8	1458.89	96.45696
9	1424.17	96.68404	10	1164.79	98.21155	11	1115.62	98.08416	12	1030.77	96.64396
13	866.846	99.10688	14	680.749	97.46471	15	423.298	98.06728			

(B)

Figure 2

(A) FTIR spectrum of ECRP before treatment and (B) FTIR spectrum of ECRP after treatment

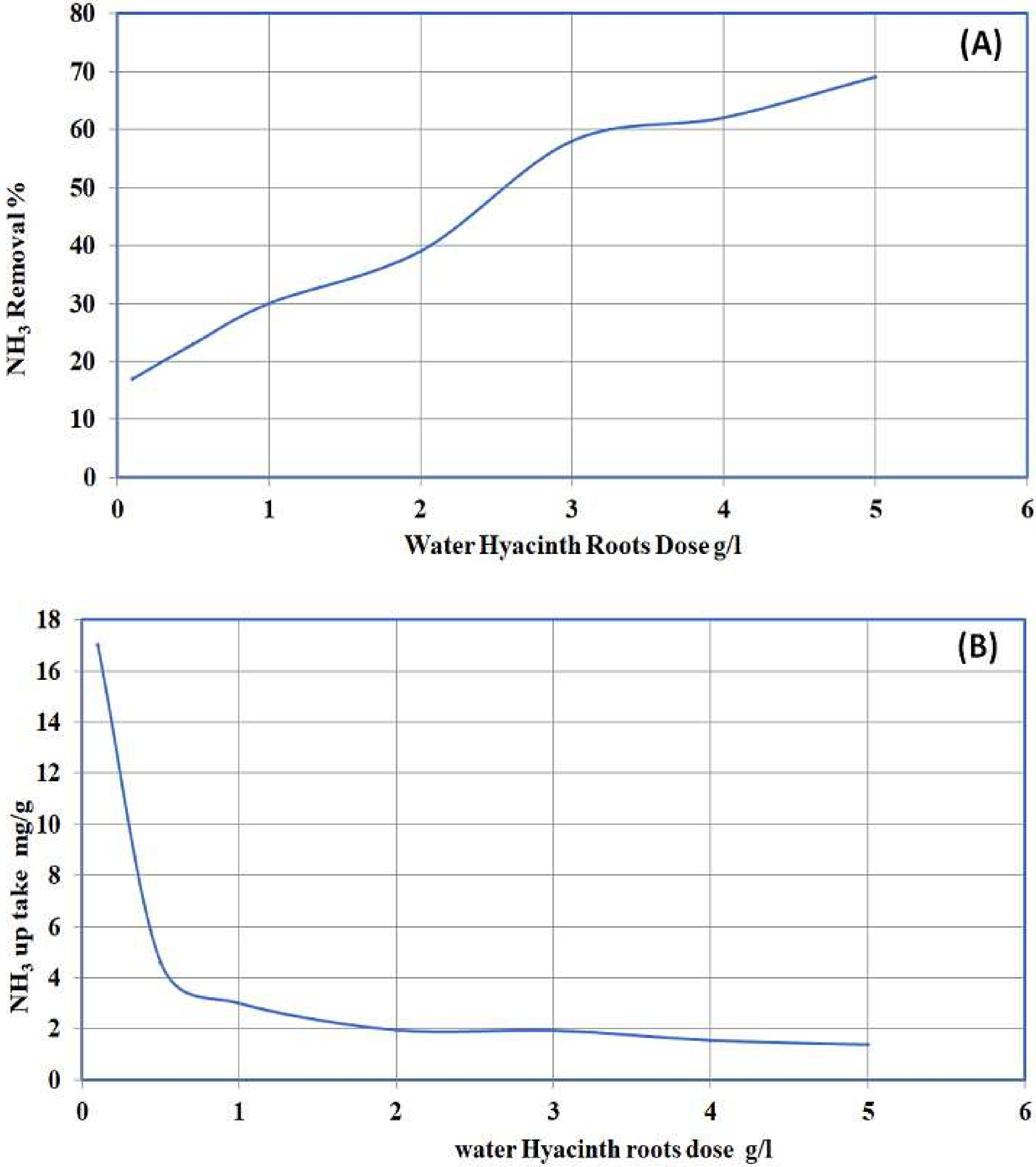


Figure 3

(A) Effect of ECRP dose on removal of ammonia and (B) Effect of ECRP dose on ammonia uptake

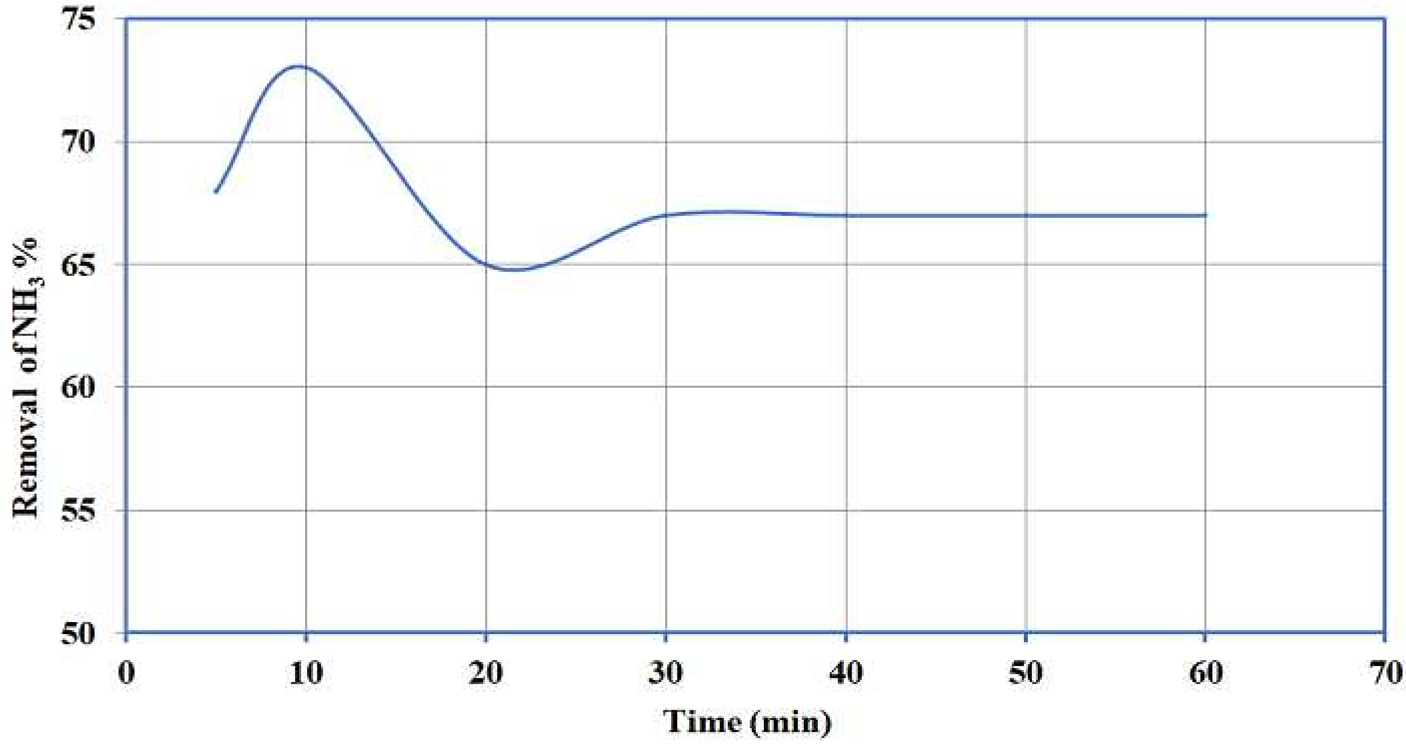


Figure 4

Effect of contact time on removal of ammonia

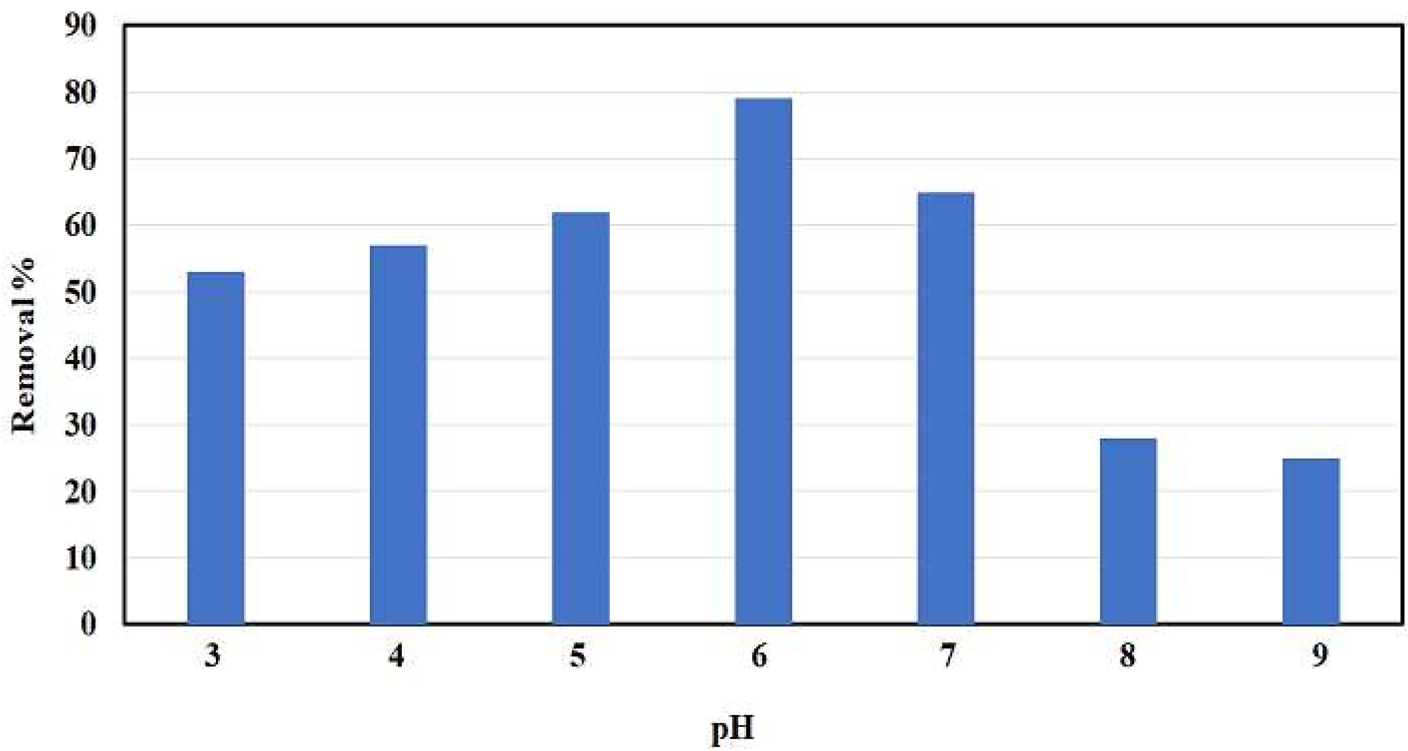


Figure 5

Effect of pH on ammonia removal

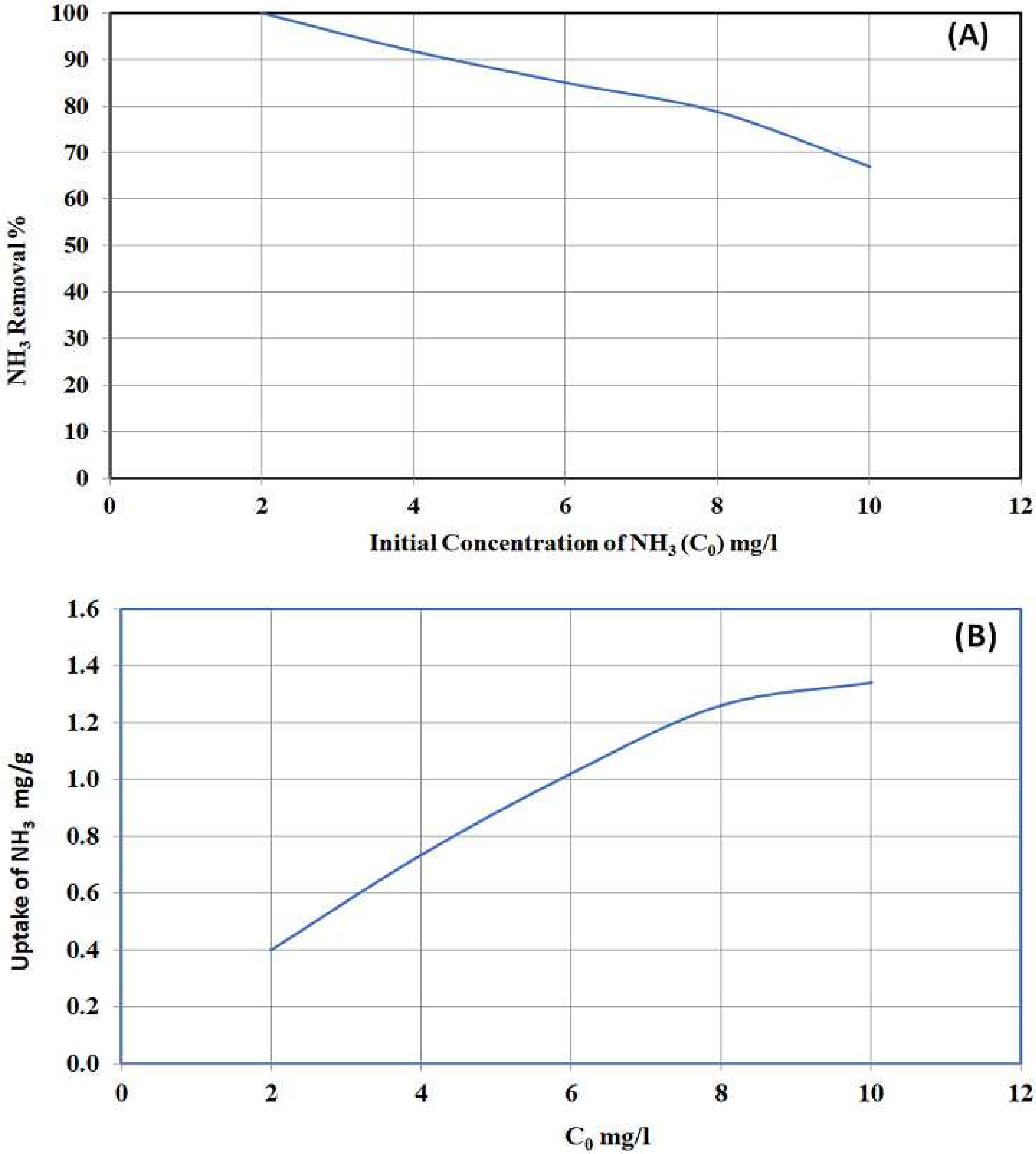


Figure 6

(A) Effect of initial concentration on removal of ammonia and (B) Effect of initial concentration on ammonia uptake

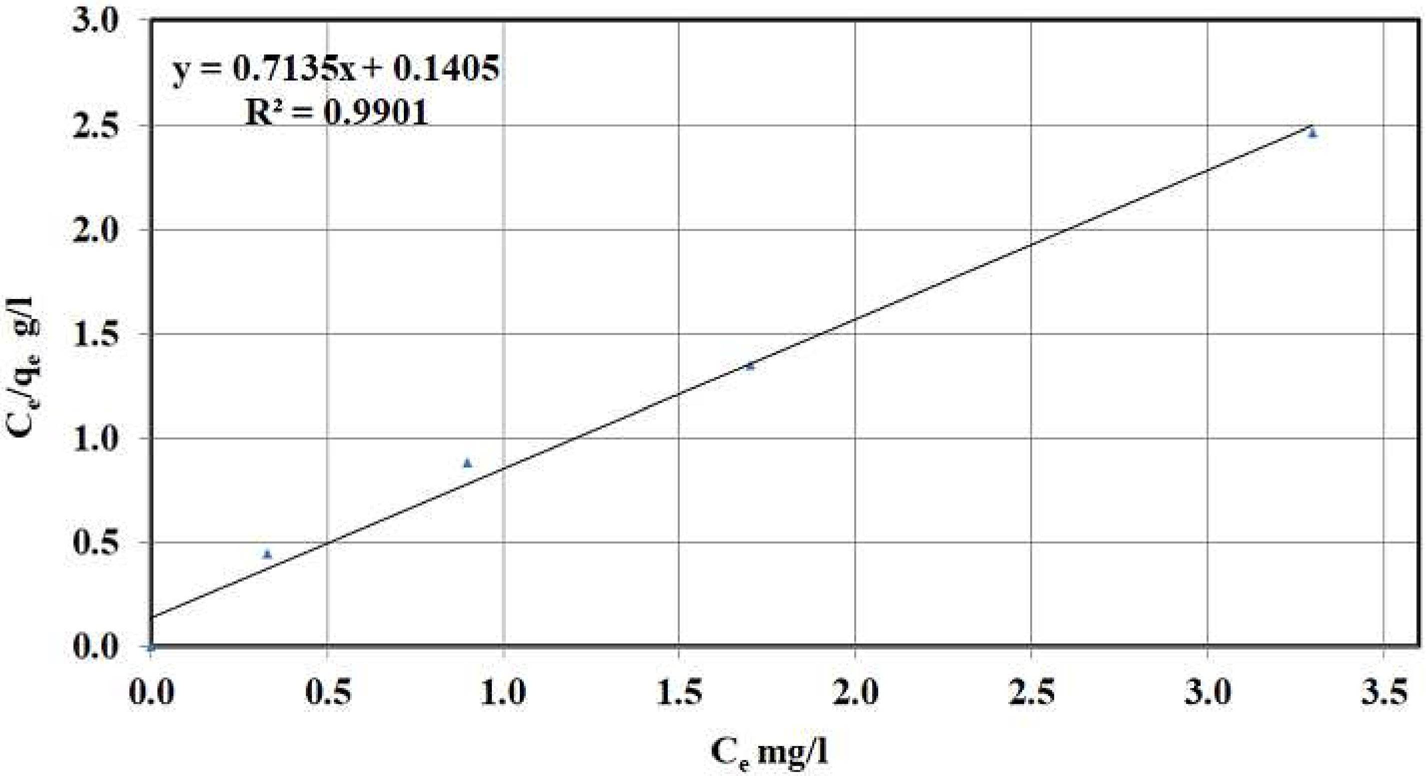


Figure 7

Langmuir plot of ECRP as adsorbent for NH3 removal

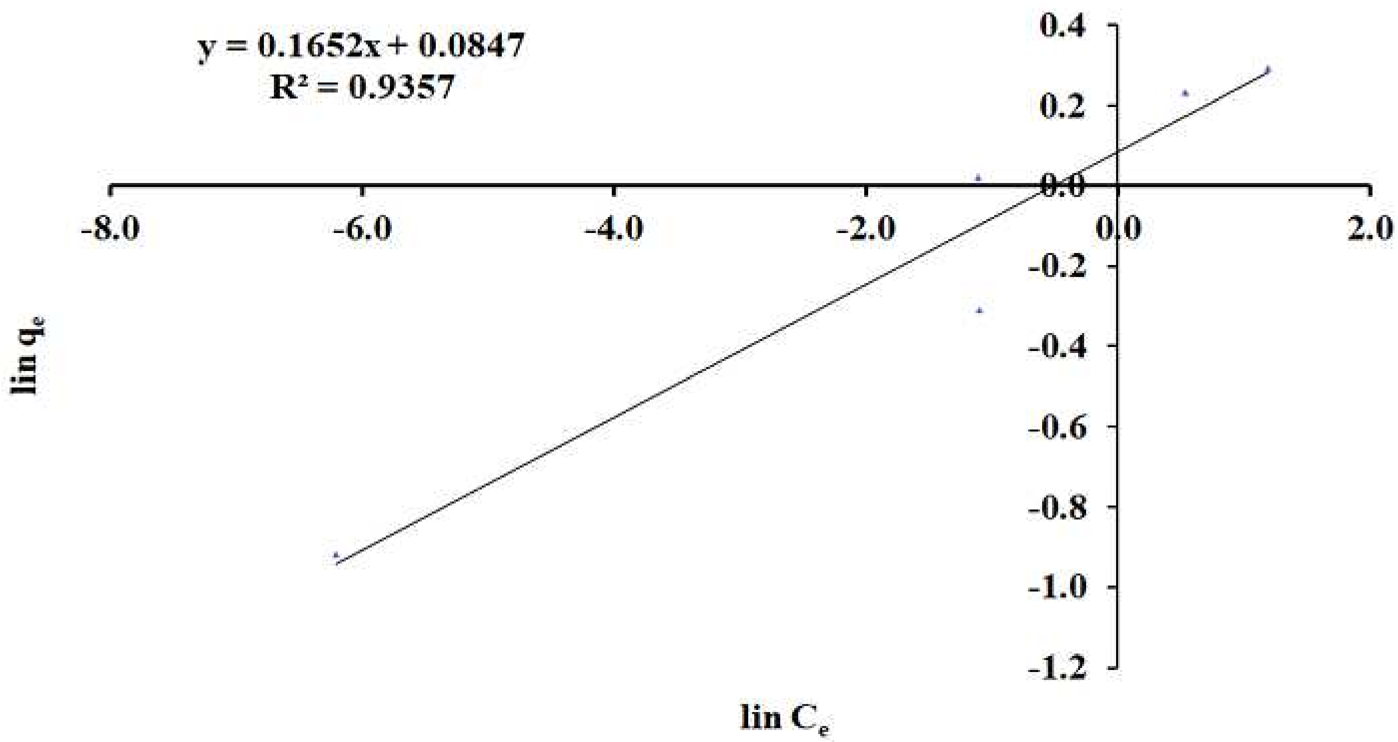


Figure 8

Plot of Freundlich isotherm for adsorption of NH3 on ECRP

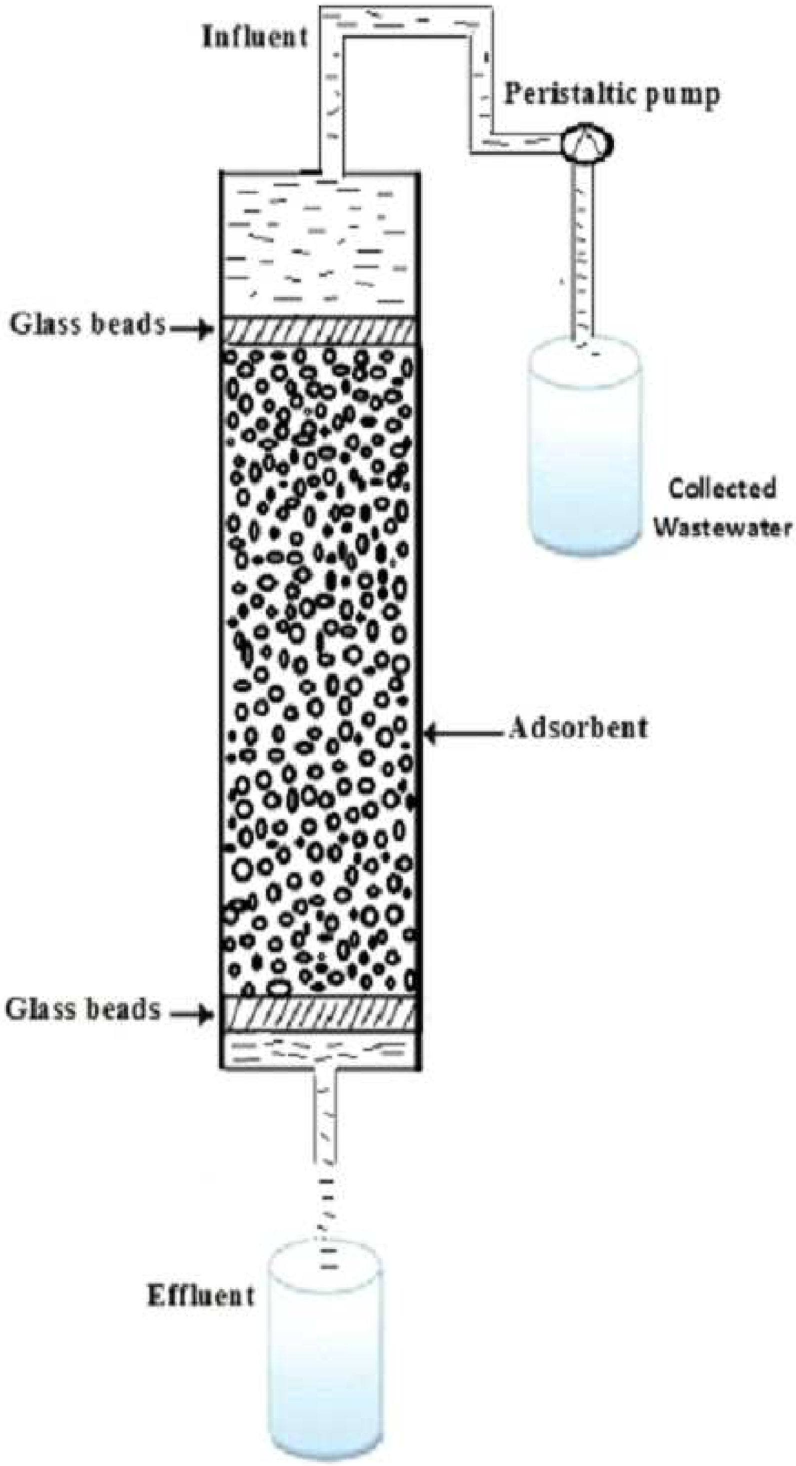


Figure 9

Adsorption column

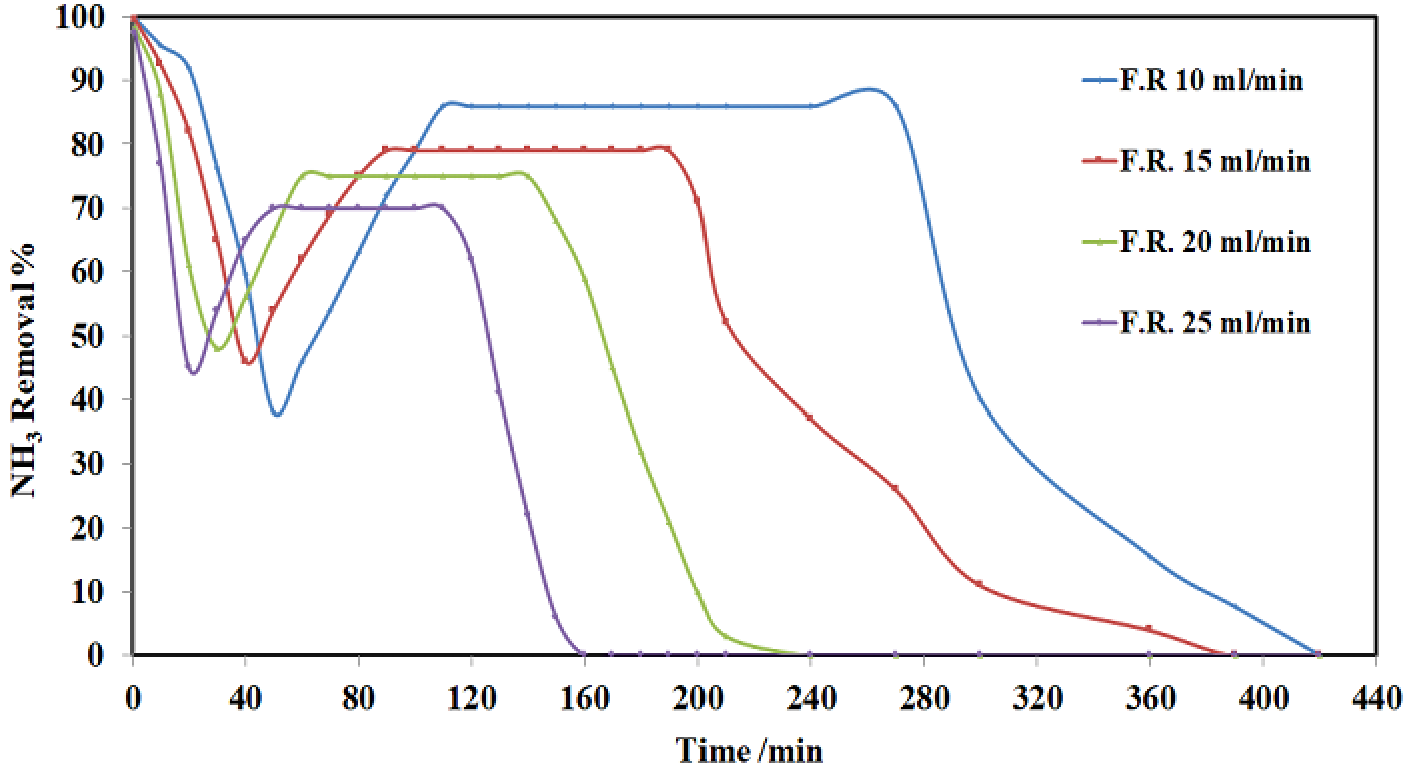


Figure 10

Effect of flow rate on ammonia removal by adsorption column

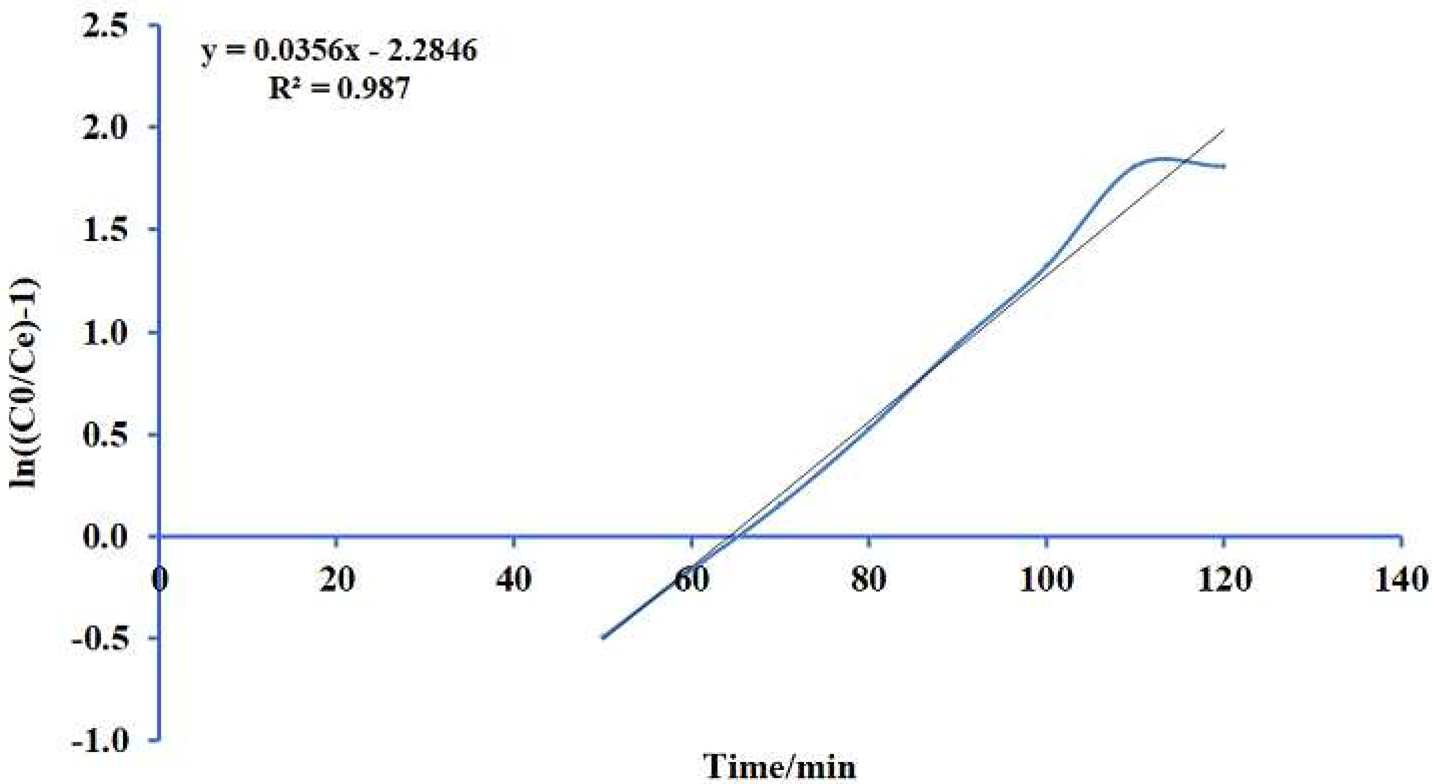


Figure 11

Plot Thomas mathematical model for ammonia adsorption by bed column at flow rate 10 ml/min

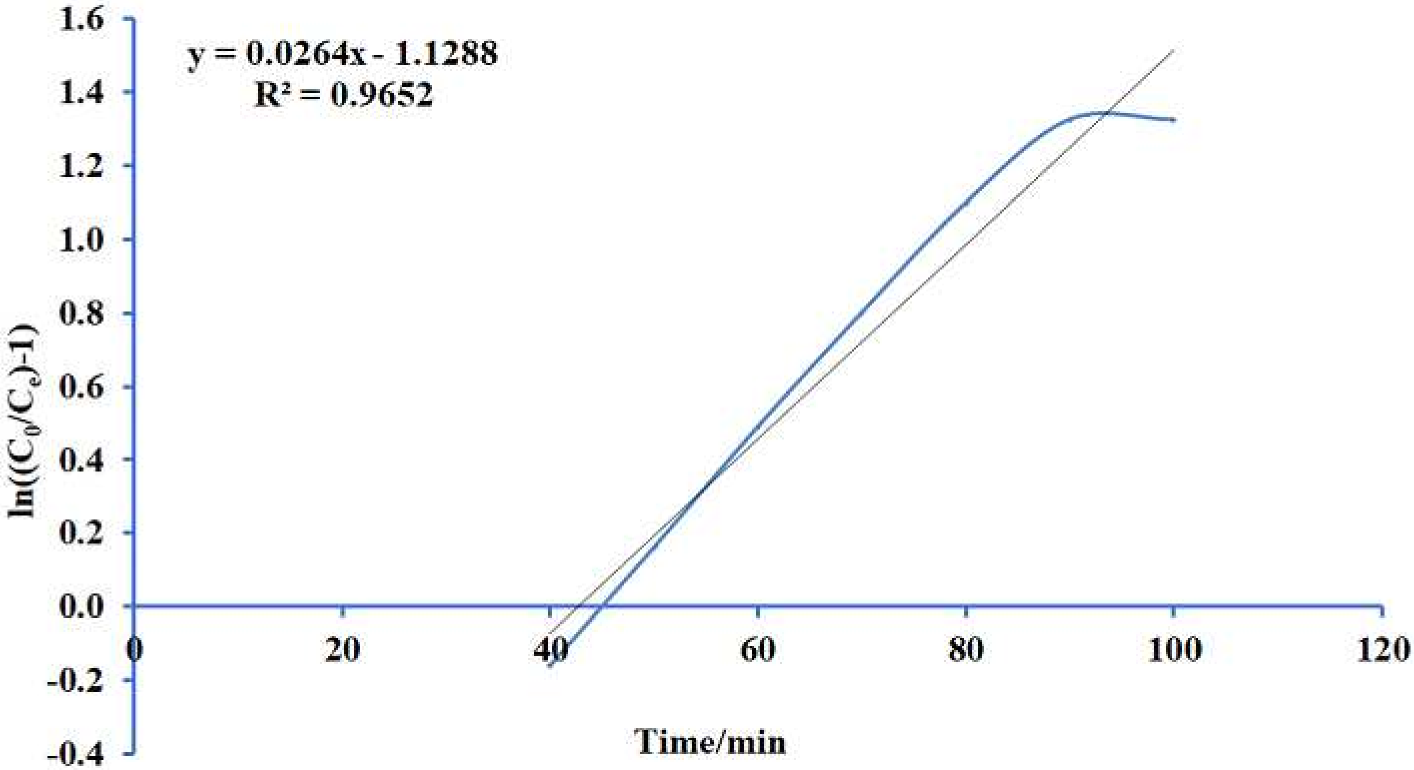


Figure 12

Plot Thomas mathematical model for ammonia adsorption by bed column at flow rate 15 ml/min

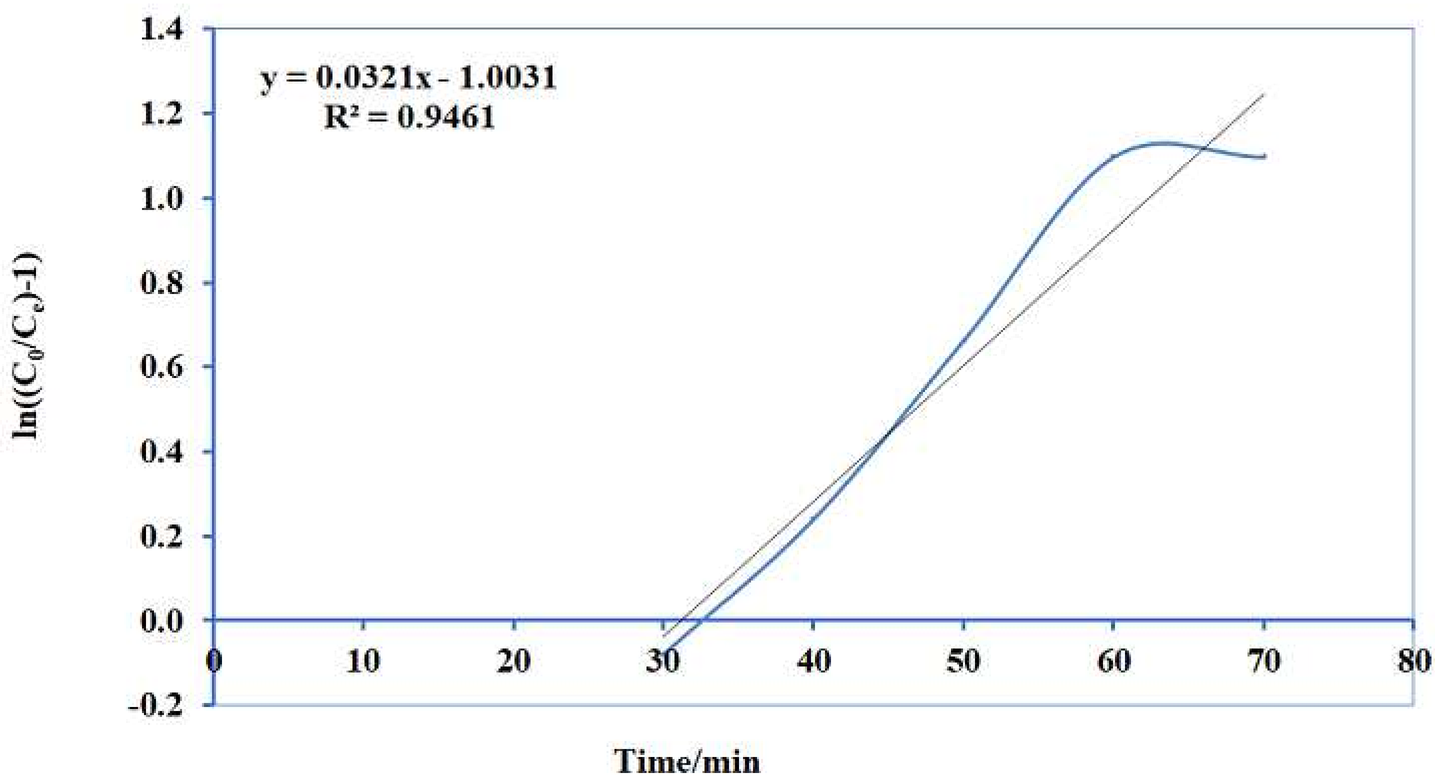


Figure 13

Plot Thomas mathematical model for ammonia adsorption by bed column at flow rate 20 ml/min

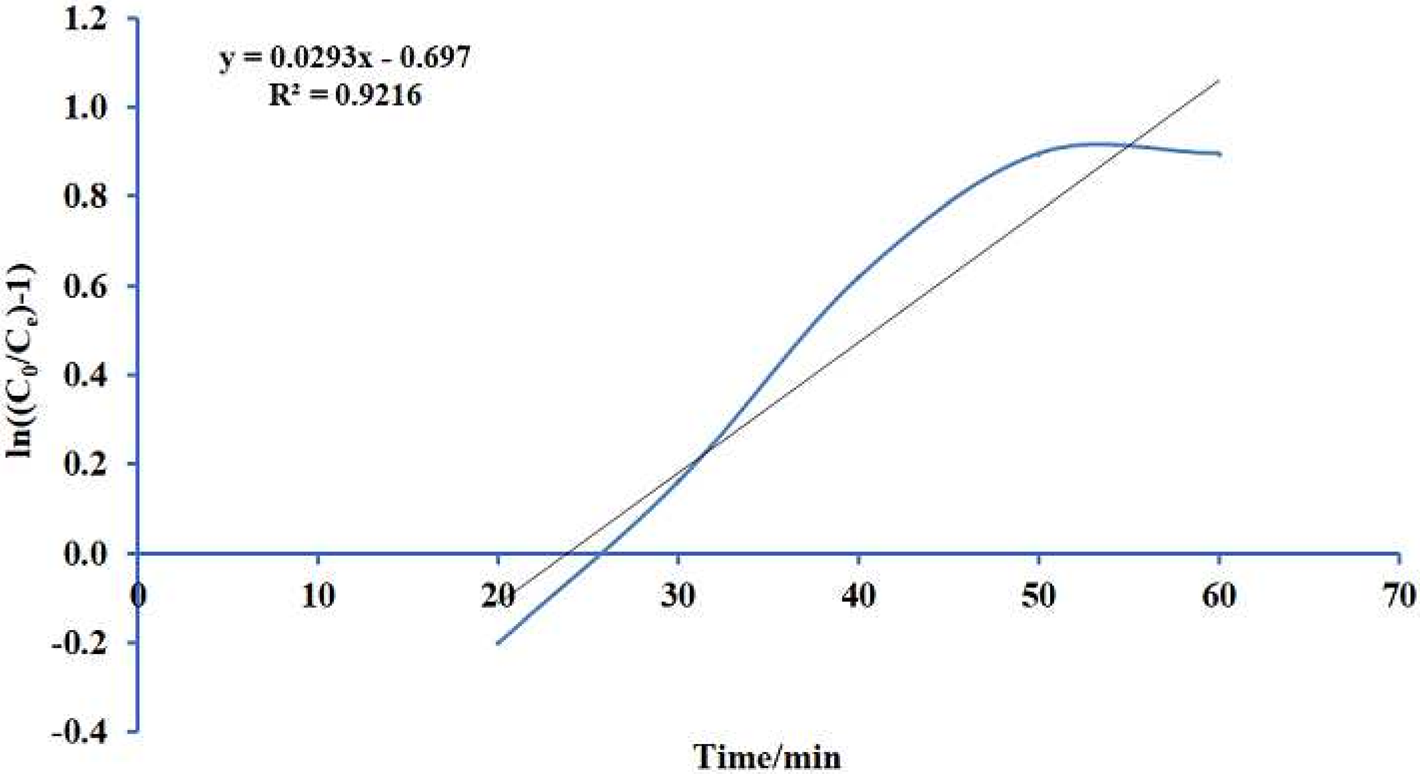


Figure 14

Plot Thomas mathematical model for ammonia adsorption by bed column at flow rate 25 ml/min

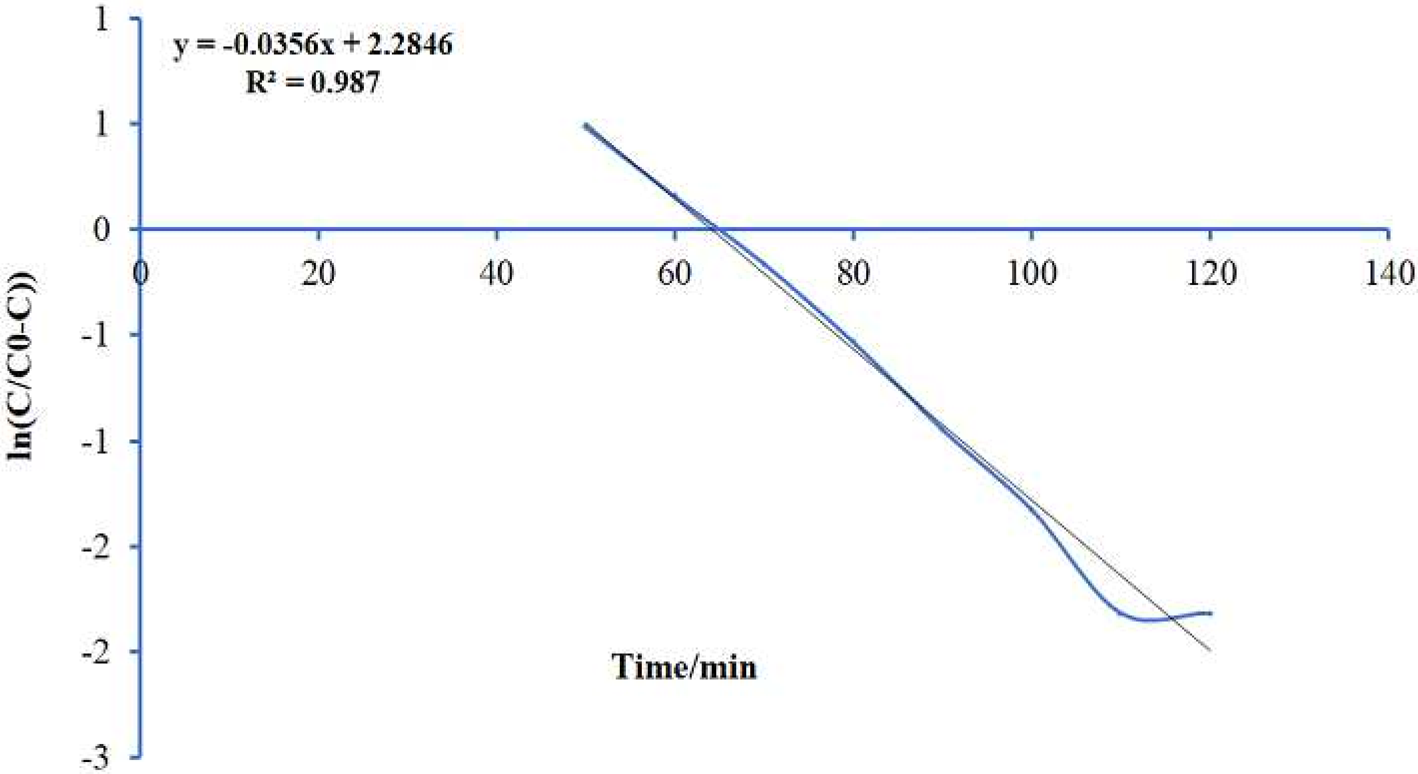


Figure 15

Plot Yoon and Nelson mathematical model for ammonia adsorption by bed column at flow rate 10 ml/min

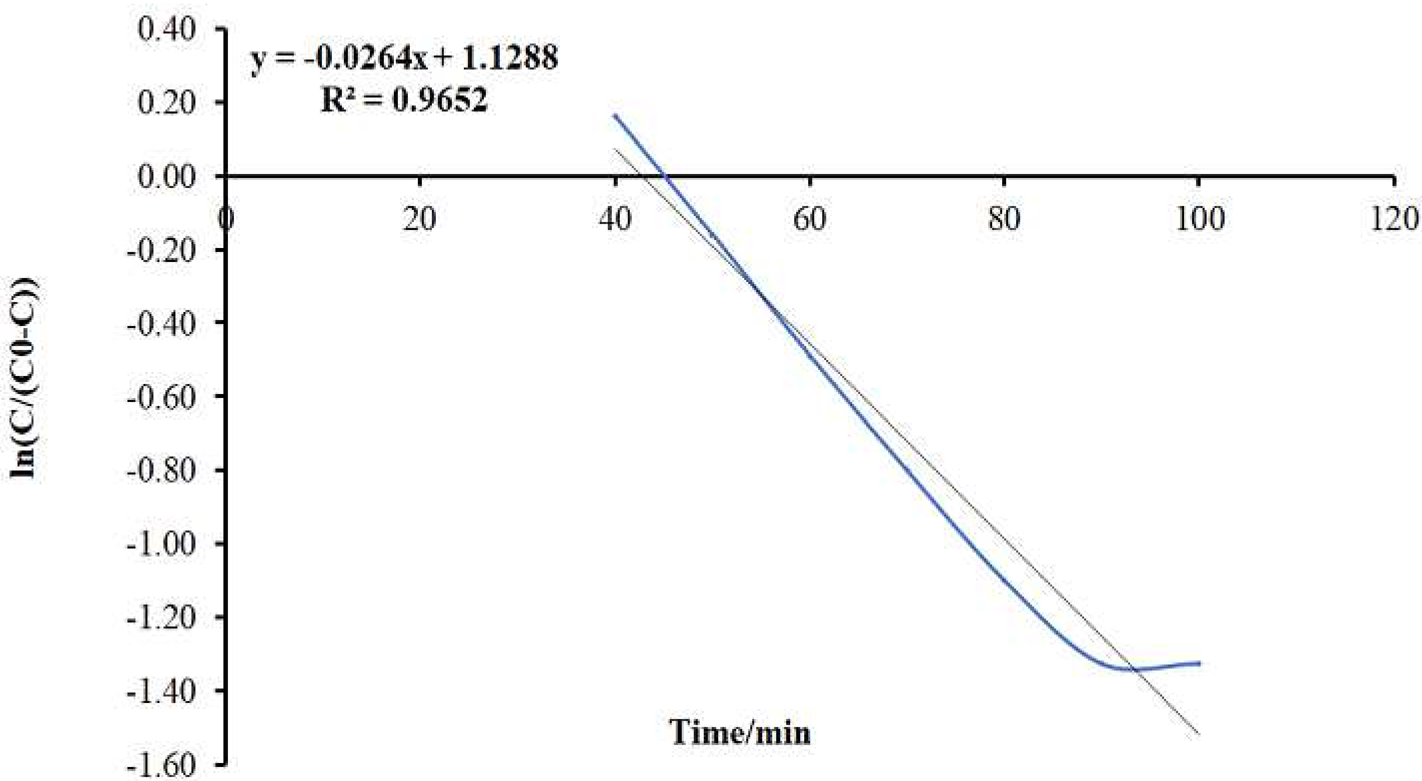


Figure 16

Plot Yoon and Nelson mathematical model for ammonia adsorption by bed column at flow rate 15 ml/min

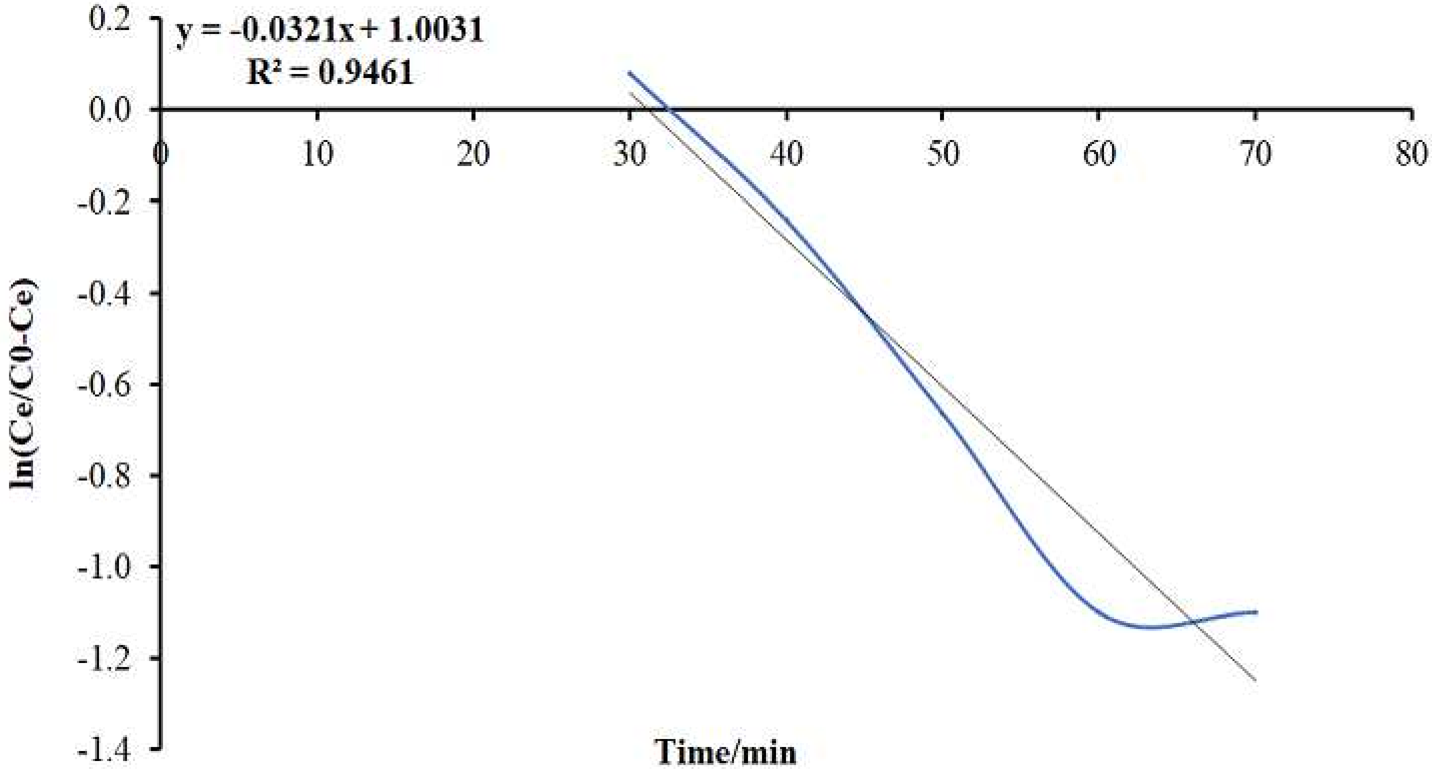


Figure 17

Plot Yoon and Nelson mathematical model for ammonia adsorption by bed column at flow rate 20 ml/min

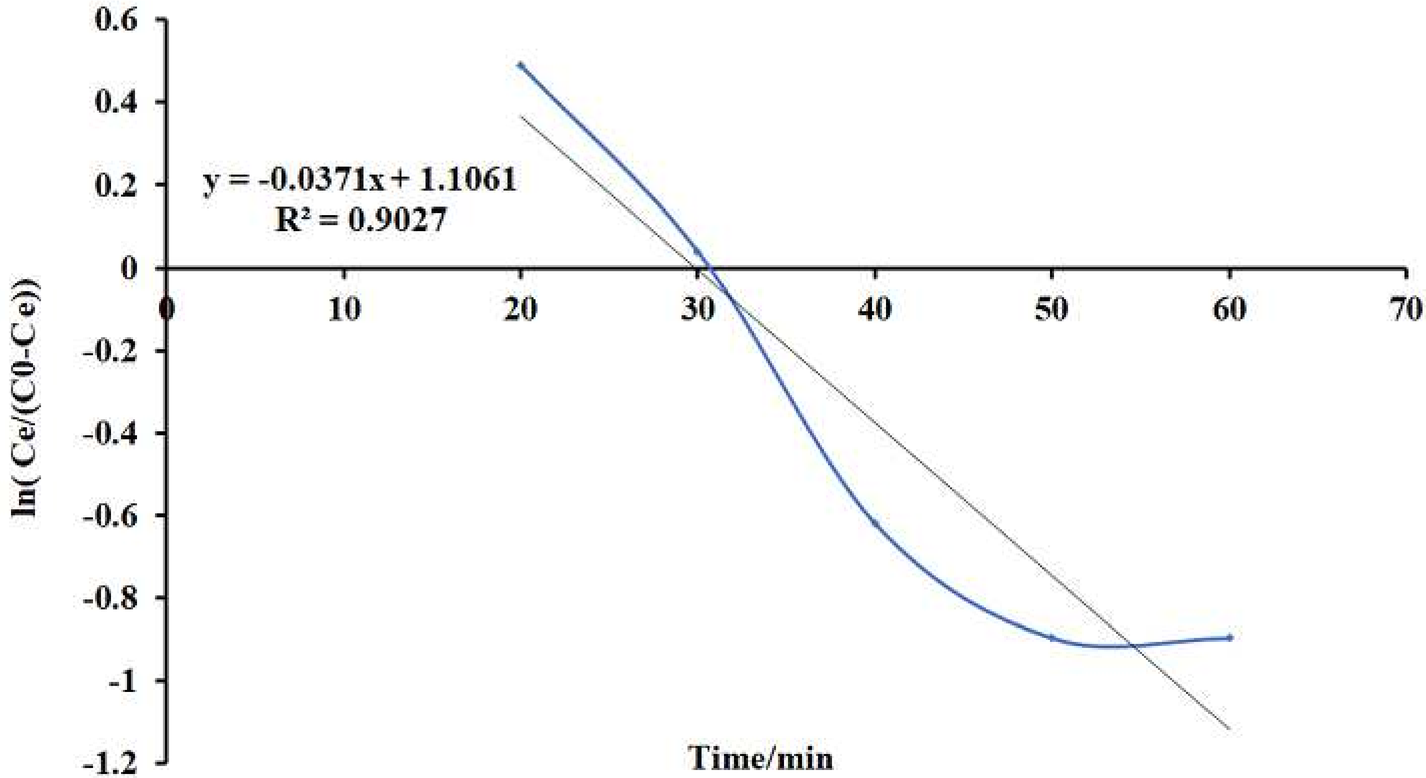


Figure 18

Plot Yoon and Nelson mathematical model for ammonia adsorption by bed column at flow rate 25 ml/min

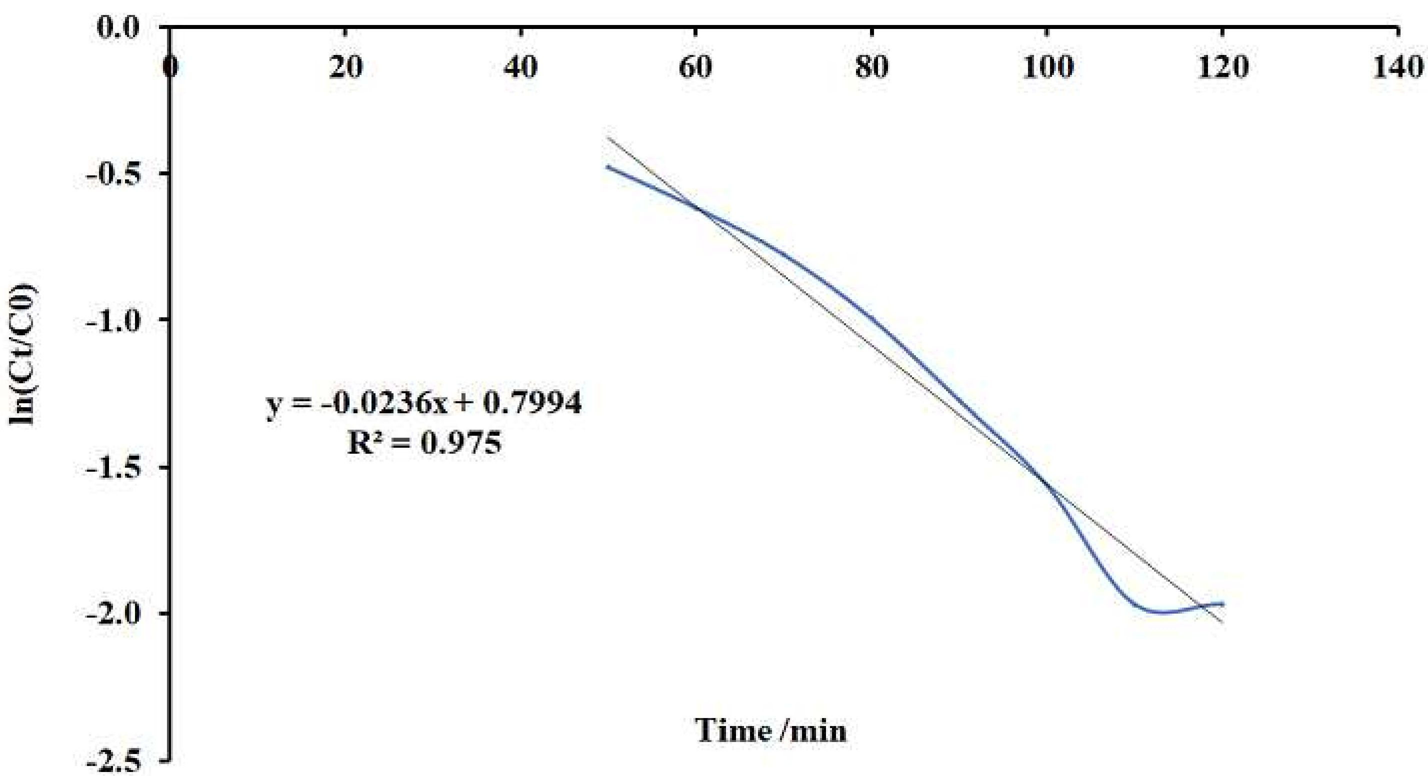


Figure 19

Plot Bohart-Adam mathematical model for ammonia adsorption by bed column at flow rate 10 ml/min

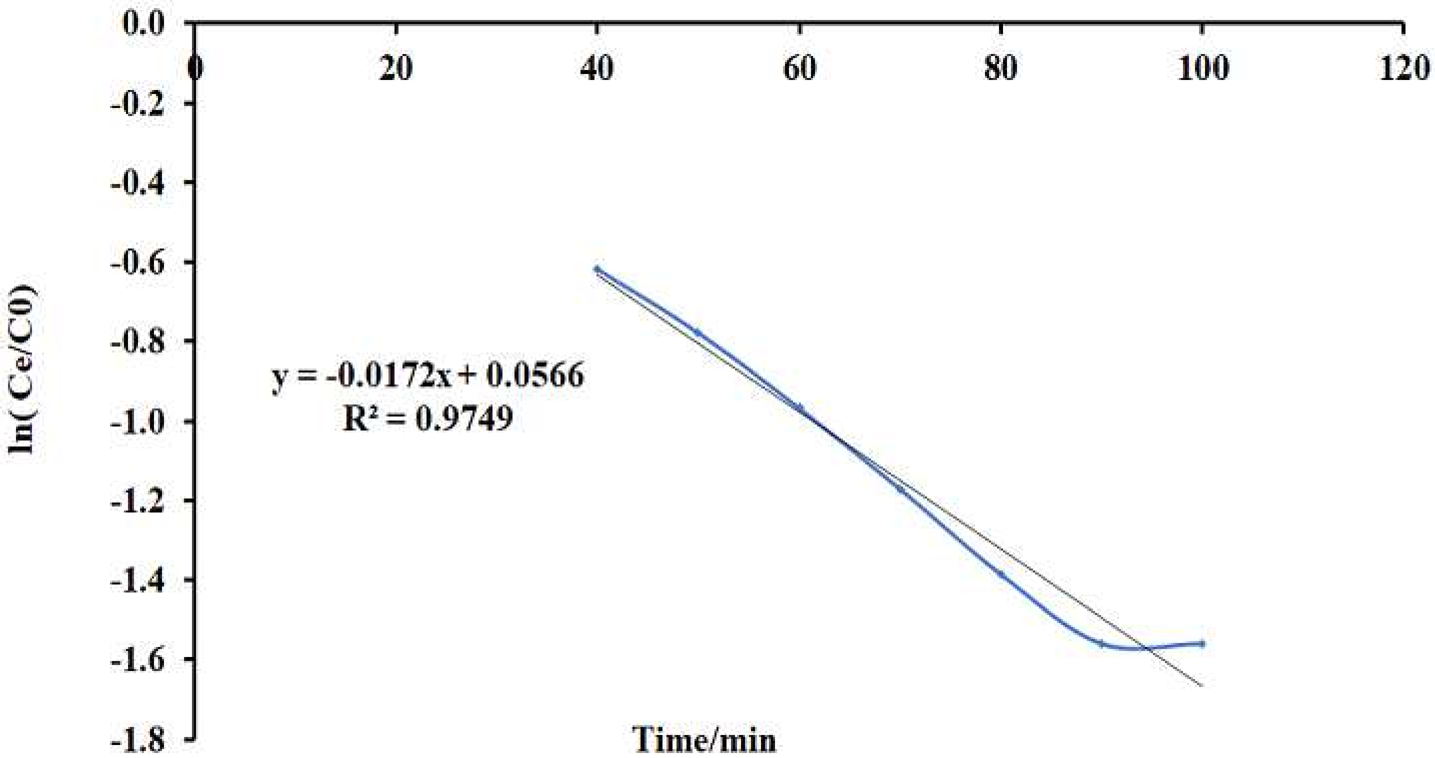


Figure 20

Plot Bohart-Adam mathematical model for ammonia adsorption by bed column at flow rate 15 ml/min

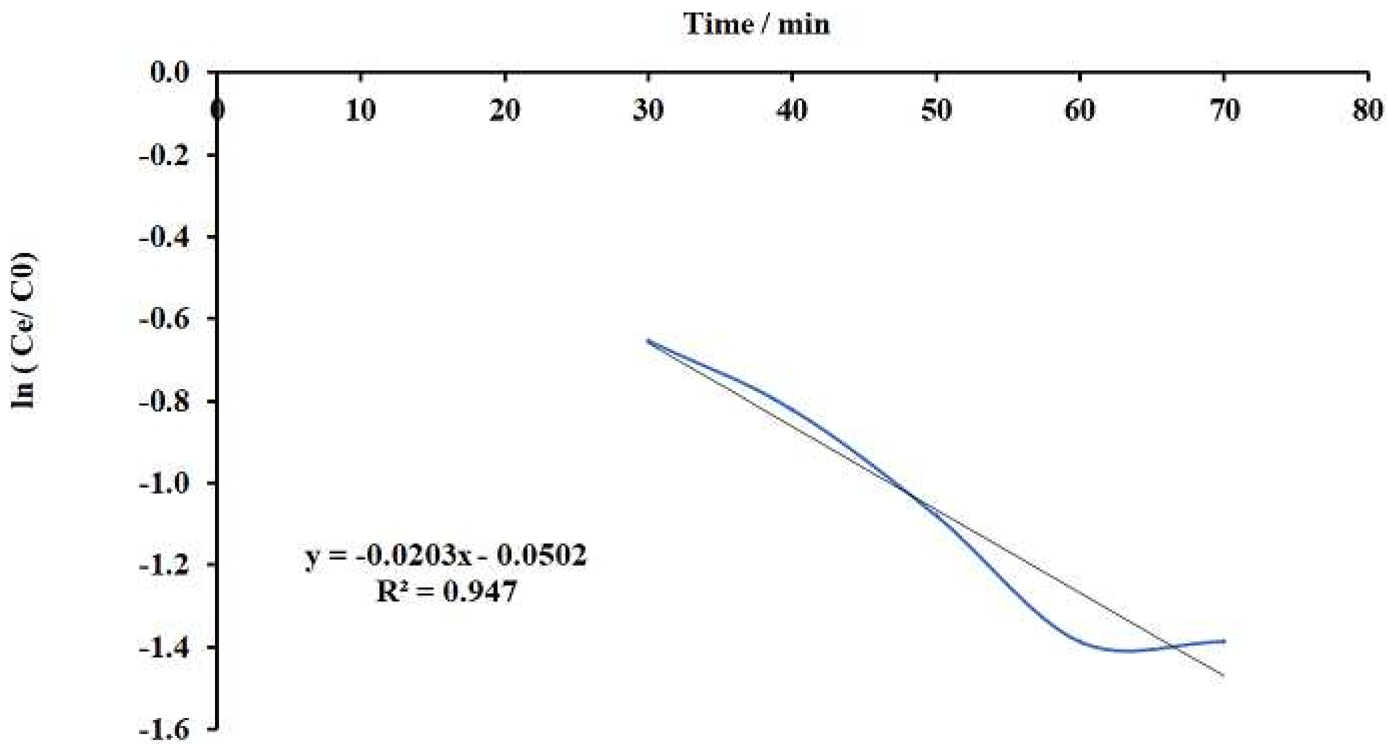


Figure 21

Plot Bohart-Adam mathematical model for ammonia adsorption by bed column at flow rate 20 ml/min

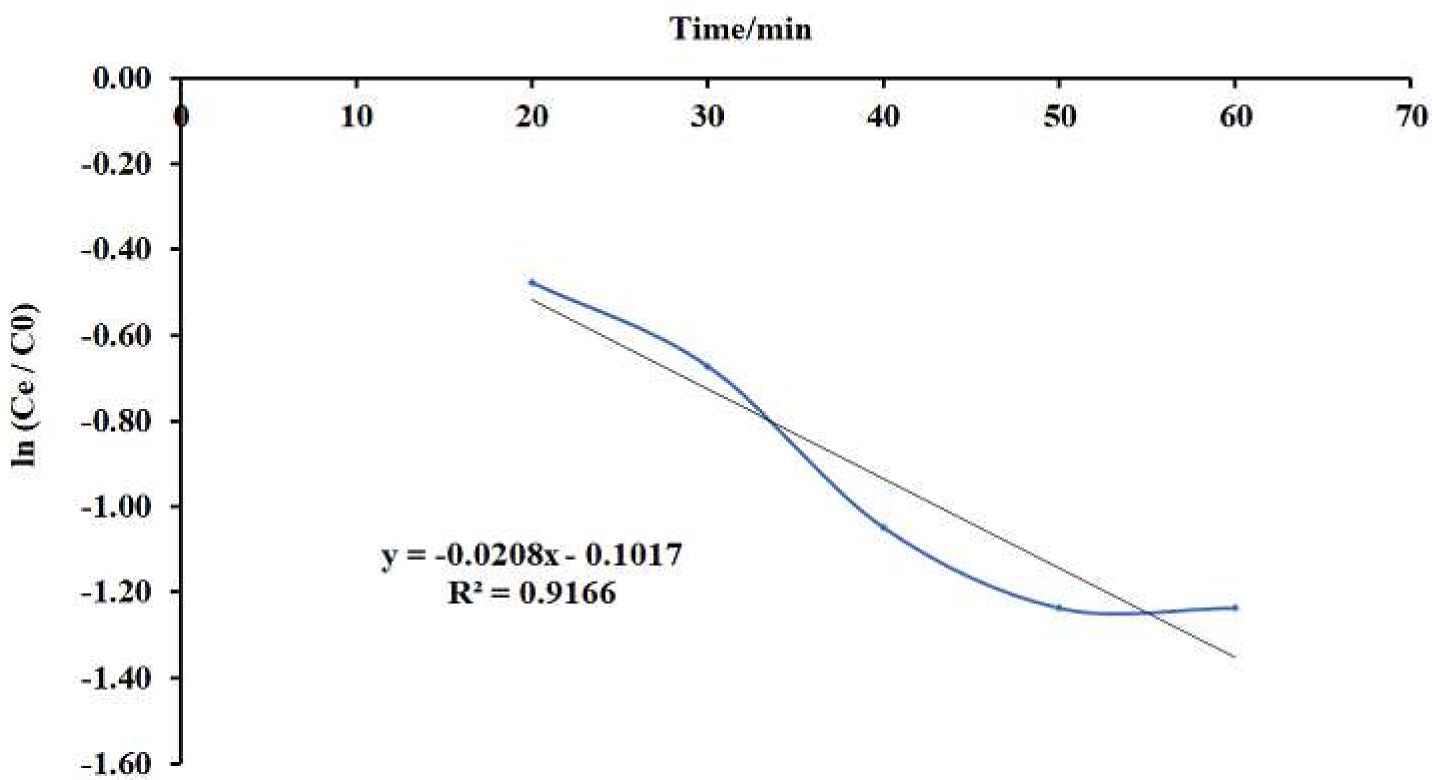


Figure 22

Plot Bohart-Adam mathematical model for ammonia adsorption by bed column at flow rate 25 ml/min

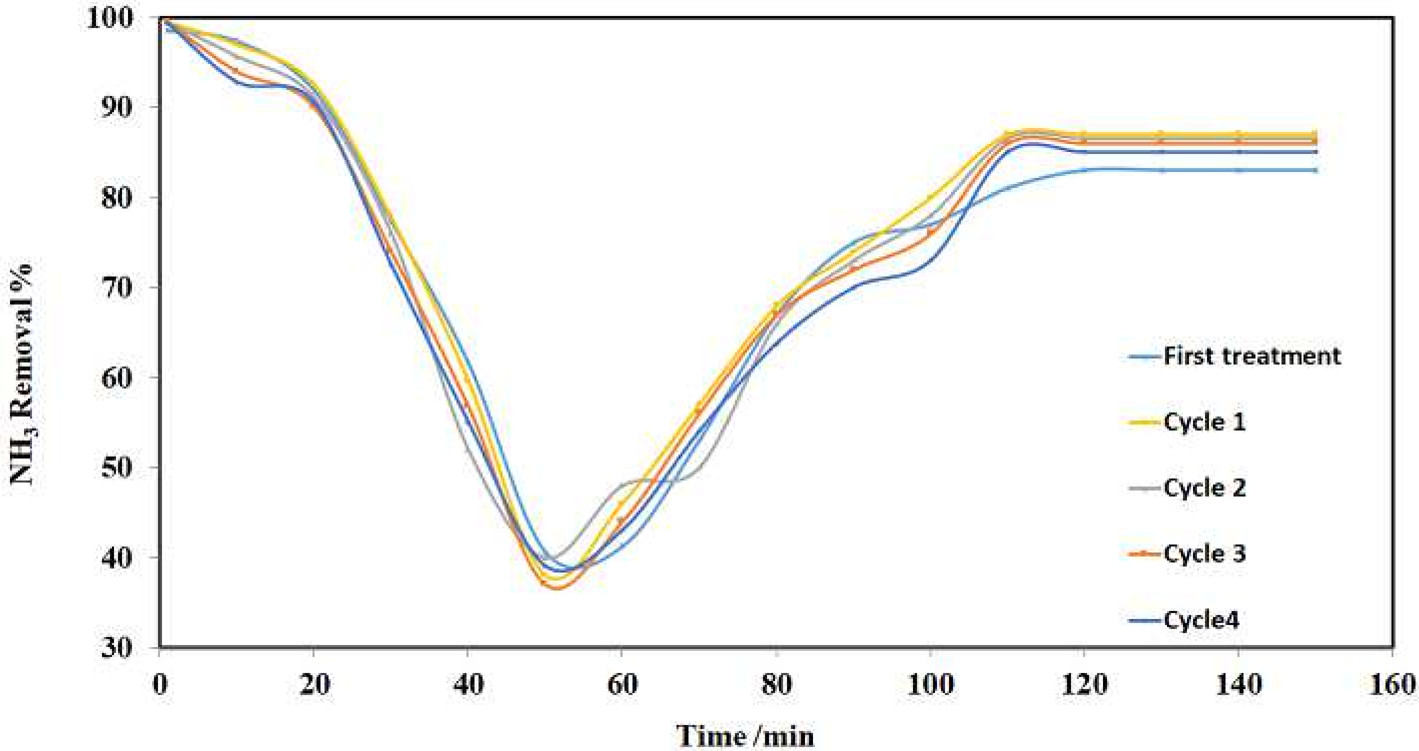


Figure 23

Adsorption recycles of ECP for ammonia removal

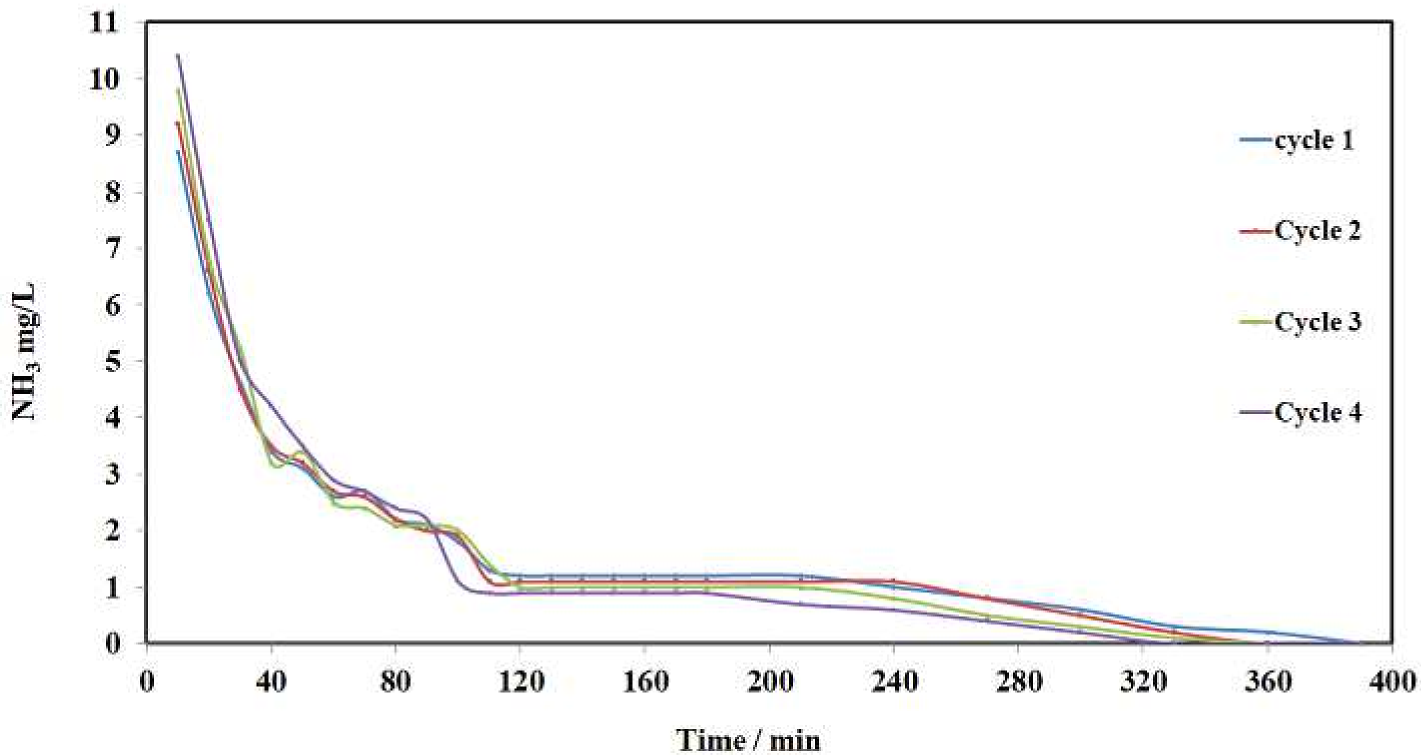


Figure 24

ammonia elution by NaCl solution at pH 12 in column system

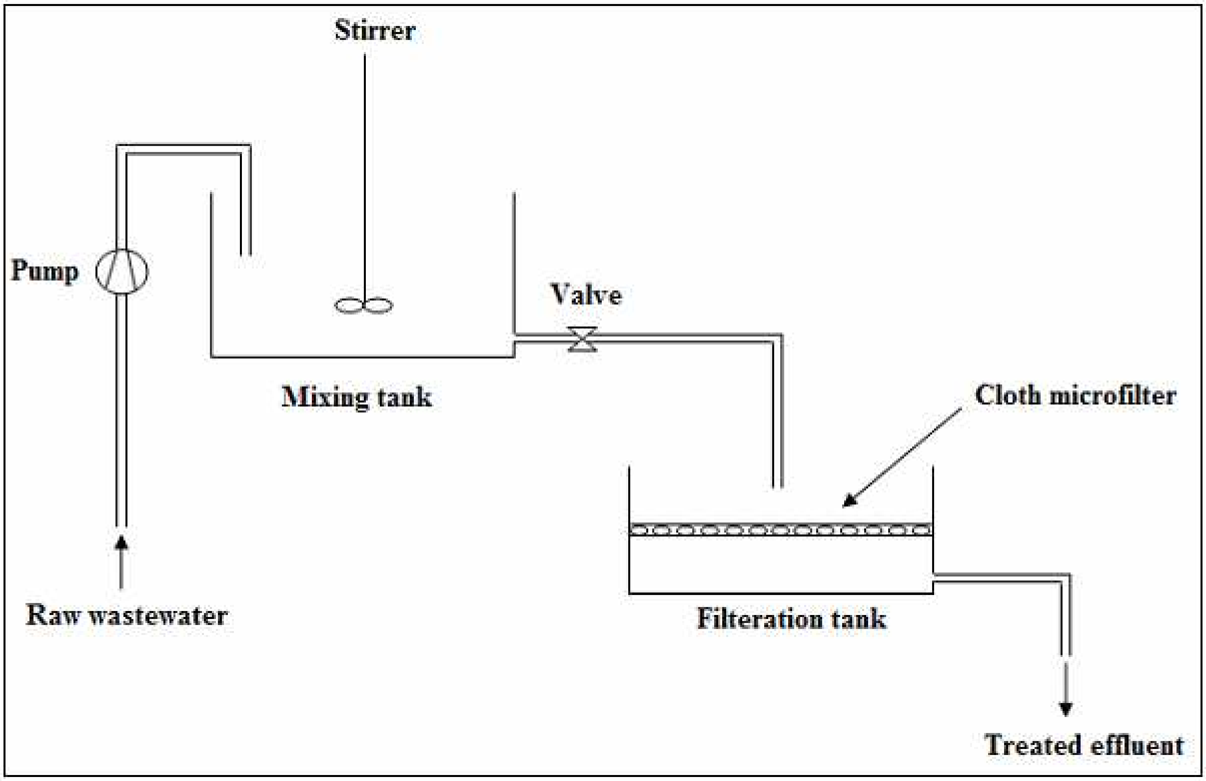


Figure 25

wastewater treatment plant