ARSENIC REMOVAL FROM DRINKING WATER USING SILICA BASED CATALYTIC MEDIA

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ABSTRACT

Arsenic is a common environmental contaminant found naturally in surface and groundwater resources used for potable supply. Typical values in the Waikato River in New Zealand are around 20 parts per billion (ppb) whereas the New Zealand drinking water standard is 10 ppb. It has become a major concern and challenge in water supply due to its toxicity and carcinogenic properties. Sources of arsenic contamination in surface and groundwater originate from both natural and anthropogenic sources. In oxygen-rich environments where aerobic conditions persist and under natural pH conditions, As (V) is predominant, whereas As (III) dominates in a moderately reducing environment with anoxic conditions such as are found in ground waters. A silica based catalytic media was assessed for arsenic removal. Bench top column and batch experiments were carried out to study the performance of the catalytic media under a range of operating conditions. The flow rate through the test columns was varied from 5 ml/min to 15 ml/min equating to a filtration rate of 0.57 to 1.7 m/hr. The pH of the water was varied from 6 to 8.5. In the batch experiments, As (V) removal was highest for low concentrations with 84 – 90 % removal at pH 8.5 while in the bench top column test, greater than 95% As (V) removal was achieved at pH 6 and 5 ml/min flowrate. Adsorption kinetics and isotherms were determined at different pH (5, 6, 7 and 8.5) and the effect of contact time was evaluated. Adsorption isotherms of As (V) were determined using the Langmuir, Freundlich, Langmuir-Freundlich and Dubinin-Radushkevich models. The results are encouraging and further studies are planned to examine the potential to separate the arsenic from water treatment plant sludge.

KEYWORDS

Arsenic removal, drinking water, catalytic media

PRESENTER PROFILE

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1   INTRODUCTION

Arsenic contamination of drinking water is known as one of the most toxic and carcinogenic elements worldwide and its causing several environmental concerns (Roghani et al., 2016). Arsenic contamination has been reported in several countries including India, China, USA, Taiwan, Vietnam, Chile, Argentina, Canada and New Zealand. Arsenic is known to cause skin diseases, cancer, diabetes and vascular diseases (Mohan and Pittman Jr., 2007). Arsenic in surface and groundwater originates from both

natural and anthropogenic sources. It is released into water bodies from sedimentary rocks, weathered volcanic rocks and from geothermal water. Human activities also release arsenic into water bodies such as mining, metallurgy, chemical manufacturing, and pesticide application (Harvey et al., 2002).

Arsenic occurs in both organic and inorganic forms in natural waters and exists in the -3, 0, +3, +5 oxidation states. The -3 and 0 elemental states are extremely rare, whereas the +3 and +5 oxidation states are commonly found in drinking water sources in the form of arsenite (As (III)) and arsenate (As (V)) (Yazdani et al., 2016). The dominant species in natural surface water bodies is As (V) while As (III) mainly exists in an anoxic environment such as in groundwater. As (III) is usually more toxic and more difficult to remove from water than As (V) (Song et al., 2015).

The World Health Organization (WHO), United States Environmental Protection Agency (US. EPA) and the Drinking Water Standards for New Zealand (DWSNZ 2005 (revised 2008)) have set the maximum contamination level (MCL) or maximum acceptable concentration (MAC) at 10 µg/L for arsenic in drinking water (DWSNZ, 2008; U.S.EPA, 2016; WHO, 2011). In order to meet the standard, a more efficient method of arsenic removal from drinking water is required. Over the last decade, several methods have evolved to effectively remove arsenic from drinking water such as precipitation, membrane processes, ion exchange, coagulation followed by filtration and adsorption (Choong et al., 2007; Litter et al., 2010; Villaescusa and Bollinger, 2008). Some of the factors that should be considered before selecting a particular treatment method include: treatment cost, arsenic disposal, operational complexity of the technology and skill required to operate the technology (Çiftçi and Henden, 2015).

Adsorption is used as an alternative to conventional removal techniques because it is considered to be relatively simple, efficient, cheap, more convenient for rural application and for regeneration (Chammui et al., 2014). Several adsorbents have been studied to remove arsenate from drinking water such as feldspars (Yazdani et al., 2016), molecular imprinted polymer (Önnby et al., 2012), amine doped acrylic ion exchange fiber (Lee et al., 2017), nanoparticle coated resin (Çiftçi and Henden, 2015), New Zealand Iron Sand (Panthi and Wareham, 2011), biochar (Zhu et al., 2016) and multiwall carbon nanotube (Addo Ntim and Mitra, 2012).

DMI-65 is a silica based catalytic media which facilitates the oxidation-precipitation-filtration processes. The media was primarily designed to remove iron and manganese without the use of potassium permanganate but can also remove arsenic as a result of co-precipitation of arsenic with iron and adsorption onto the media. Therefore it is necessary to add iron in the form of ferric chloride if no iron is present in the water. Other advantages of DMI-65 include stable and satisfactory performance over a wide pH range (5.8 – 8.6), only sodium hypochlorite feed required, long life and no need for regeneration after initial activation (Quantum Filtration Medium, 2014).

This study investigated the adsorptive behavior of As (V) onto DMI-65 as part of studies assessing potential options for the separate removal of arsenic at water treatment plants. The effect of pH of the aqueous solution, contact time and initial concentration of arsenic (V) were examined to find the optimum adsorption conditions in batch experiments. Column experiments were conducted to examine the effect of flowrate and pH on arsenic (V) removal.

2   EXPERIMENTAL METHOD

2.1   MATERIALS

DMI-65 was obtained from Quantum Filtration Medium Property Ltd and activated using sodium hypochlorite (NaOCl) prior to use for both the column and batch adsorption experiments. The stock solution of As (V) (100 mg/L) was prepared by dissolving As_2O_5 (Sigma-Aldrich, 99%) in deionized water (18.2 MΩ cm-1; Barnstead, EASYpure). The stock solution is diluted with deionized water to get the required As (V) solutions used in this experiments. A stock solution of 50 g/L Ferric Chloride ($FeCl_3$) and 5 mg/L NaOCl were prepared in a volumetric flask and diluted to the required concentrations of 50 mg/L $FeCl_3$ and 5 mg/L NaOCl. The pH adjustments were performed using 0.1 M hydrochloric acid (HCl) and 0.1 M sodium hydroxide (NaOH) solutions. All chemicals and reagents used in this work were analytical grade.

2.2   INSTRUMENTS

Inductively coupled plasma mass spectrometry (ICP-MS) was used to determine As (V) removal efficiency in both the column and batch adsorption experiments. The column experiments were conducted using an AKTA Explorer machine and the batch adsorption experiments were conducted using a Ratek orbital shaker. The pH of the solutions were measured using a Eutech pH150 pH/temperature meter

2.3   MEDIA ACTIVATION

In the batch adsorption experiments, 15 ml Falcon tubes containing 1 g of DMI-65 were prepared. All the samples were soaked with 5 ml of 12.5 % NaOCl and left for 24 hours. After 24 hours, the media was washed repeatedly until the free chlorine residual in the solution dropped to 0.1 – 0.3 ppm.

In the column experiments, 115 g of DMI 65 was measured and placed in a beaker. The media was soaked in 200 ml of 12.5 % NaOCl for 48 hours. After activation, the media was placed in a glass column, 33 mm in diameter and 265 mm in height. The media was backwashed using the AKTA Explorer machine until the free chlorine residual reduced to 0.1 – 0.3 ppm.

2.4   BATCH TESTS

All batch experiments were conducted by adding 1g of DMI 65 to 50 ml of As (V) solution (20 g/L) in a 100 ml Erlenmeyer conical flask and agitating at 130 rpm on an orbital shaker at room temperature (21 ± 2 °C). In addition, 0.25 mg/L of $FeCL_3$ and 0.4 mg/L NaOCl were also added to the solution. The initial pH was adjusted with 0.1 M NaOH and 0.1 M HCl. After a predetermined contact time, media samples were filtered through Whatman-42 filter papers (0.45 μm) and the arsenic concentration in the filtrate was measured using ICP-MS.

Adsorption kinetics experiments were conducted by shaking 1 g of activated DMI-65 with 50 ml of As (V) solution containing 0.06 mg/L As (V) at different pH (5, 6, 7 and 8.5). The sorption amount of As (V) was measured at different time intervals. The mixture was agitated at 130 rpm in an orbital shaker at room temperature for 24 hour to reach equilibrium conditions.

Adsorption isotherm experiments were conducted as follows: 1 g of activated DMI 65 was mixed with 50 ml As (V) solution with concentrations ranging from 0.03 – 40 mg/L As (V) at different pH (5, 6, 7 and 8.5). The mixture containing different As (V) concentration was agitated at 130 rpm in an orbital shaker at room temperature for 24 hour to reach equilibrium. All adsorption experiments were performed in duplicate.

The amount of As (V) adsorbed, q_t (mg/g) at time t, was calculated according to equation (1):

$$q_t = \frac{[(C_o - C_t)V]}{W} \qquad (1)$$

Where C_o and C_t (mg/L) are the liquid phase concentrations of As (V) at initial time zero and time t respectively, V is the volume of the Arsenic solution (L) and W is the mass (g) of DMI 65 used for As (V) adsorption.

The percentage of As (V) removal was calculated according to equation (2):

$$R\% = \left[\frac{C_o - C_e}{C_o}\right] X\ 100 \qquad (2)$$

Where C_e is the equilibrium concentration in the solution (mg/L).

2.4 COLUMN TESTS

All column experiments were performed inside a glass column (33 mm in diameter and 265 mm in height) containing 115 g activated DMI 65 attached to the AKTA Explorer machine. Different concentrations of As (V) solutions (0.01 – 0.05 mg/L) containing 0.25 mg/L $FeCl_3$ and 0.4 mg/L NaOCl was prepared for the column experiments. The addition of $FeCl_3$ is essential to form a complex with the arsenic while NaOCl acts as an oxidant in the solution. Other factors evaluated in the column experiment are flow rate (5, 10 and 15 ml/min) and pH (6, 7 and 8.5).

3 RESULTS AND DISCUSSION

3.1 EFFECT OF CONTACT TIME AND ADSORPTION KINETICS

Batch adsorption experiments were carried out to investigate the time required to reach equilibrium conditions as shown in Figure 1. In this study, 1 g of DMI-65 was added to 50 ml of 0.06 mg/L As (V) solution and shaken at 130 rpm for 24 hours. Samples for analysis were taken at specific time intervals. In this study, three different kinetic models were applied to determine the kinetic data for As (V) adsorption and to select the most suitable model for defining the experimental q_e value. The three models are pseudo-first-order, pseudo-second-order and Elovich kinetic models. The pseudo-first-order non-linear model can be expressed as shown in equation (3):

$$q_t = q_e(1 - \exp^{-K_1 t}) \qquad (3)$$

Equation (3) can further be linearized by the following equation:

$$\log(q_e - q_t) = \log q_e - \frac{K_1 t}{2.303} \qquad (4)$$

The non-linear form of pseudo-second-order model is given as:

$$q_t = \frac{K_2 q_e^2 t}{(1 + q_e K_2 t)} \qquad (5)$$

Equation (5) can further be linearly expressed by the following equation:

$$\frac{t}{q_t} = \frac{1}{K_2 q_e^2} + \frac{t}{q_e} \qquad (6)$$

Where K_1 and K_2 is the pseudo-first order (min⁻¹) and pseudo-second-order (g/mg.min) rate constant respectively, t is the time (min), q_e and q_t represent the quantity of As (V) adsorbed (mg/g) on the surface of DMI-65 at equilibrium and at time t (min) respectively (Gulnaz et al., 2005).

The Elovich kinetic model can be expressed as:

$$q_t = \left(\frac{1}{\beta}\right) \ln (\alpha\beta) + \left(\frac{1}{\beta}\right) \ln (t) \qquad (7)$$

Where α (mg/g min) and β (g/mg) are the initial adsorption rate constant and the Elovich adsorption constant respectively (Sen Gupta and Bhattacharyya, 2011).

Figure 1: Adsorption kinetic plots for As (V) (adsorbent dosage = 20 g/L, initial concentration = 0.06 mg/L, contact time = 24 hours, temperature = 19°C, agitation speed = 130 rpm. (a) pH 5, (b) pH 6, (c) pH 7 and (d) pH 8.5.
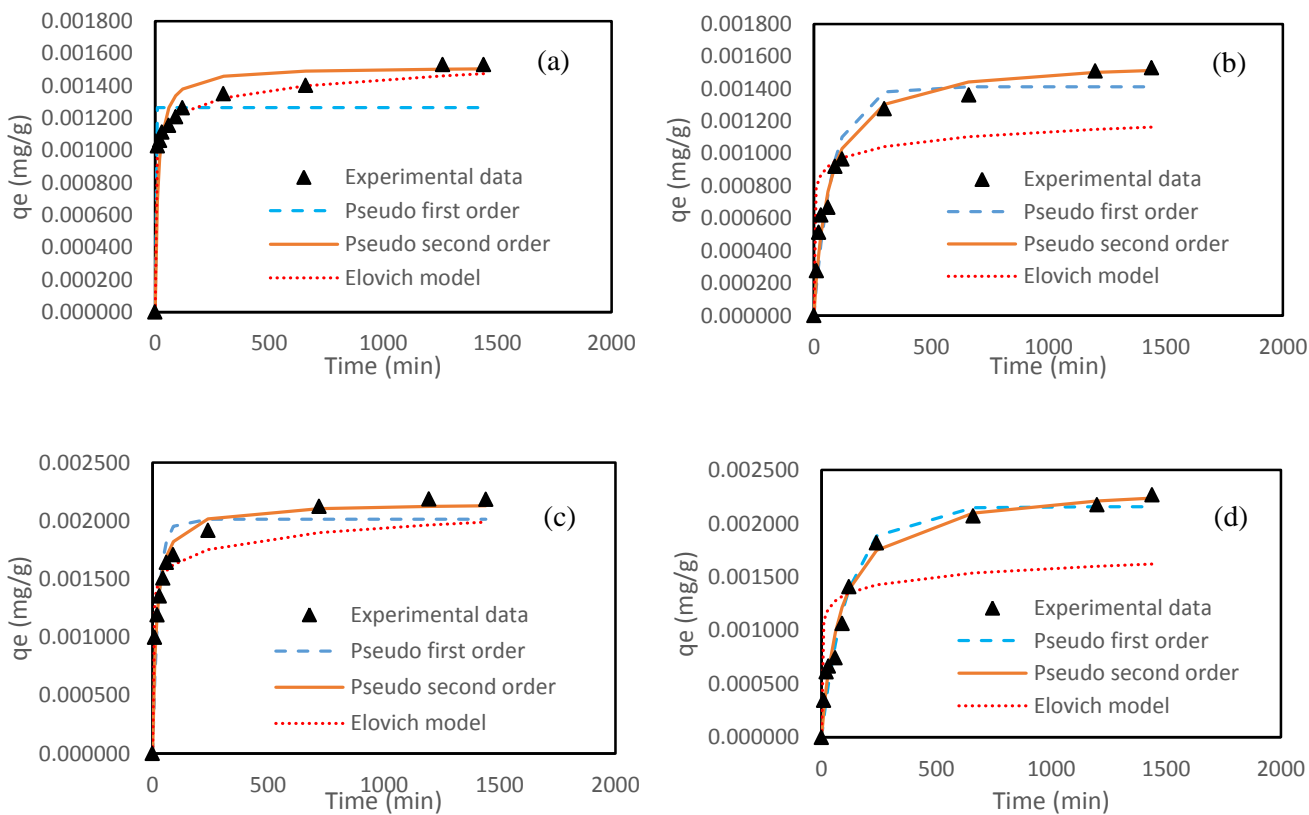

Figure 2: Effect of contact time on As (V) removal by DMI-65 (adsorbent dosage = 20 g/L, initial concentration = 0.06 mg/L, contact time = 24 hours, temperature = 19°C, agitation speed = 130 rpm. (a) pH 5, (b) pH 6, (c) pH 7 and (d) pH 8.5.
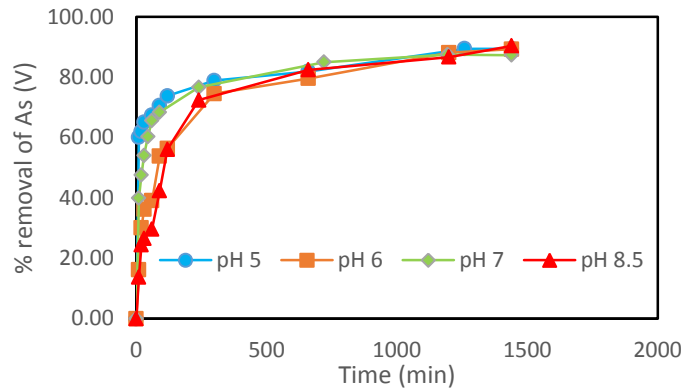
Figure 1 shows the kinetic plots for As (V) at different pH. The rate of As (V) adsorption was rapid in the first 20 min for pH 5 and pH 7 whereas a pH 6 and 8.5 shows a gradual adsorption process occurs before reaching equilibrium. For all pH, equilibrium was reached after 6 hours of constant shaking. At seen from Figure 2, 90.4 % of As (V) in the solution was removed by DMI 65 at pH 8.5. A maximum As (V) removal for pH 5, 6 and 7 was 89.5, 89.3 and 87.4 % respectively. These results clearly show that more than 87 % of the initial arsenic concentration was removed for all pH values considered in this study and all results are below the MAV of 0.010 mg/L.

Table 1: *Pseudo-first-order, Pseudo-second-order and Elovich models for As (V) adsorption on DMI-65 at different initial pH conditions. (a) Linear plot data (b) Non-linear plot data.*

(a)

Model	Parameters	pH 5	pH 6	pH 7	pH 8.5
First-pseudo-order kinetic model	K_1 (min^{-1})	0.0055	0.0032	0.0039	0.0025
	q_e (mg/g)	0.00073	0.00104	0.00098	0.00157
	R^2	0.884	0.961	0.964	0.912
Second-pseudo-order kinetic model	K_2 (g/mg.min)	28.77	9.90	20.34	4.95
	q_e (mg/g)	0.00154	0.00158	0.00222	0.00222
	R^2	0.999	0.999	0.999	0.998
Elovich kinetic model	α (mg/g)	0.869	0.123	0.352	0.224
	β (g/mg.min)	10000.00	3333.33	5000.00	2500.00
	R^2	0.985	0.984	0.966	0.963

(b)

Model	Parameters	pH 5	pH 6	pH 7	pH 8.5
First-pseudo-order kinetic model	K_1 (min^{-1})	0.8999	0.0126	0.0388	0.0086
	q_e (mg/g)	0.00126	0.00141	0.00201	0.00216
	R^2	0.827	0.944	0.921	0.971
Second-pseudo-order	K_2 (g/mg.min)	55.00	9.9026	28.4718	4.9492

kinetic model	q_e (mg/g)	0.00151	0.00158	0.00215	0.00237
	R^2	0.891	0.978	0.983	0.980
Elovich kinetic model	α (mg/g)	0.301	0.226	0.334	0.222
	β (g/mg.min)	10389.15	13126.17	7600.00	9189.76
	R^2	0.854	0.531	0.793	0.470

The non-linear and linear regression analyses parameters of pseudo-first-order kinetic, pseudo-second-order kinetic and Elovich kinetic models for As (V) using DMI 65 are presented in Table 1. The kinetic parameters were determined by fitting the experimental data to non-linear kinetic models. It was observed that the values of the correlation coefficient (R^2) for the pseudo-second order model are higher than for both pseudo-first-order and Elovich kinetic models for all pH values considered in this study. Figure 3 (a) and (b) show the non-linear and linear pseudo-second-order kinetic models. Also the values of q_e obtained from the linear pseudo-second-order model are close to experimental values of q_e (0.00154, 0.00158, 0.00222 and 0.00222 mg/g) for pH 5, 6, 7 and 8.5 respectively. These show that the kinetics of arsenic adsorption onto DMI-65 fit very well with the pseudo-second-order rate kinetic model ($R^2 > 0.999$). The high R^2 value of 0.999 indicated that chemisorption could be the dominant mechanism for As (V) adsorption onto DMI-65 (Alijani and Shariatinia, 2017; Ye et al., 2017). The supremacy of pseudo-second-order model over the pseudo-first-order and Elovich models has been reported in other studies (Asmel et al., 2017; Bhaumik et al., 2015; Çiftçi and Henden, 2015).

Figure 3: The pseudo second order rate kinetics model fitted the adsorption kinetics of As (V) removal by DMI-65 (adsorbent dosage = 20 g/L, initial concentration = 0.06 mg/L, contact time = 24 hours, temperature = 19°C, agitation speed = 130 rpm, pH (5, 6, 7 and 8.5). (a) Non-linear model (b) Linear model
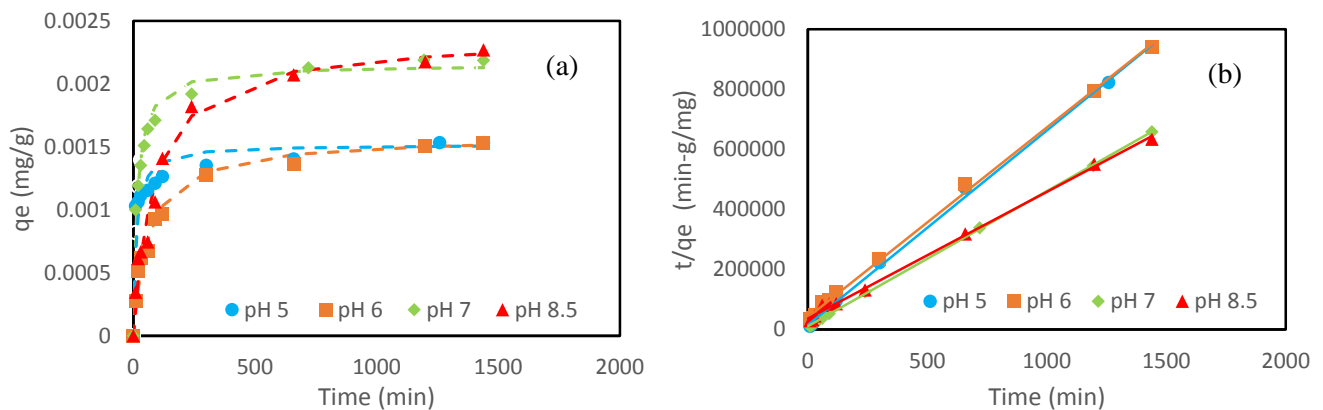
3.2   ADSORPTION ISOTHERMS

Four adsorption isotherms models were used in this study to explain the interaction between an adsorbent and an adsorbate. In this present study, the isotherms used to find the best fitted model were the Langmuir, Freundlich, Langmuir-Freundlich and Dubinin-Radushkevich (D-R) models (Mandal et al., 2013; Zeng, 2004).

The Langmuir equation can be expressed as:

$$q_e = \frac{K_L q_m C_e}{1 + K_L C_e} \qquad (8)$$

Equation (8) can further be linearized as shown in equation (9)

$$\frac{C_e}{q_e} = \frac{1}{q_m K_L} + \frac{C_e}{q_m} \qquad (9)$$

Where q_e is the amount of As (V) adsorbed at equilibrium (mg/g), C_e represents the equilibrium concentration of As (V) in the aqueous solution (mg/L), q_m is the maximum adsorption capacity (mg/g) and K_L is the Langmuir constant (L/mg).

The Freundlich equation can be expressed as:

$$q_e = K_F C_e^{\frac{1}{n}} \qquad (10)$$

Equation (10) can further be linearized as shown in equation (11)

$$\log q_e = \log K_F + \frac{1}{n}\log C_e \qquad (11)$$

Where K_F is the Freundlich constant (mg/g) and $1/n$ is a constant related to the adsorption intensity.

The Langmuir-Freundlich equation can be expressed as:

$$q_e = \frac{K_L q_m C_e^{\frac{1}{n}}}{1 + K_L C_e^{\frac{1}{n}}} \qquad (12)$$

The Dubinin - Radushkevic equation can be expressed as:

$$q_e = q_s \exp(-K_{DR}\varepsilon^2) \qquad (13)$$

$$\varepsilon = RT \ln\left(1 + \frac{1}{C_e}\right) \qquad (14)$$

Equation (13) can be linearized as shown in equation (15)

$$\ln q_e = \ln q_s - K_{DR}\varepsilon^2 \qquad (15)$$

Where K_{DR} is D-R isotherm constant (mol²/KJ²), ε is the Polanyi potential, q_s is the isotherm saturation capacity (mg/g), R is the universal gas constant (8.314 Jmol^{-1}K^{-1}) and T is the temperature in Kelvin (K).

Table 2:   Estimated isotherms parameters for As (V) adsorption using DMI-65

Model	Parameters	pH 5	pH 6	pH 7	pH 8.5
Langmuir	q_m (mg/g)	0.130	0.129	0.170	0.237
	K_L (L/mg)	2.056	1.941	1.218	0.769
	R^2	0.985	0.975	0.984	0.979
Freundlich	K_F (mg/g)	0.071	0.071	0.083	0.095
	n	3.383	3.214	2.540	2.226
	R^2	0.872	0.936	0.966	0.991

| Langmuir-Freundlich	q_m (mg/g)	0.125	0.908	0.165	0.202
	K_L (L/mg)	1.342	0.909	1.001	0.908
	n	2.116	0.579	2.527	2.428
	R^2	0.966	0.941	0.966	0.989
Dubinin-Raduchkevich	q_s (mg/g)	0.113	0.114	0.147	0.174
	K_{DR} (mol^2/KJ^2)	0.069	0.080	0.117	0.127
	R^2	0.987	0.929	0.893	0.913

This adsorption study was conducted using 1 g of DMI-65 in 0.05 L of solution containing As (V) at various concentrations in the range of 0.03 – 40 mg/L, pH (5, 6, 7 and 8.5), contact time of 24 hours and agitation speed of 130 rpm. Figure 4 shows the - Langmuir, Freundlich, Langmuir-Freundlich and D-R isotherms fitted to data points for As (V) adsorption onto DMI 65. All the parameters shown in Table 2 were determined by nonlinear regression of the experimental data using excel-solver software.

Figure 4:   Adsorption isotherms of As (V) on DMI-65 (adsorbent dosage = 20 g/L, contact time = 24 hours, temperature = 19°C, agitation speed = 130 rpm. (a) pH 5, (b) pH 6, (c) pH 7 and (d) pH 8.5.
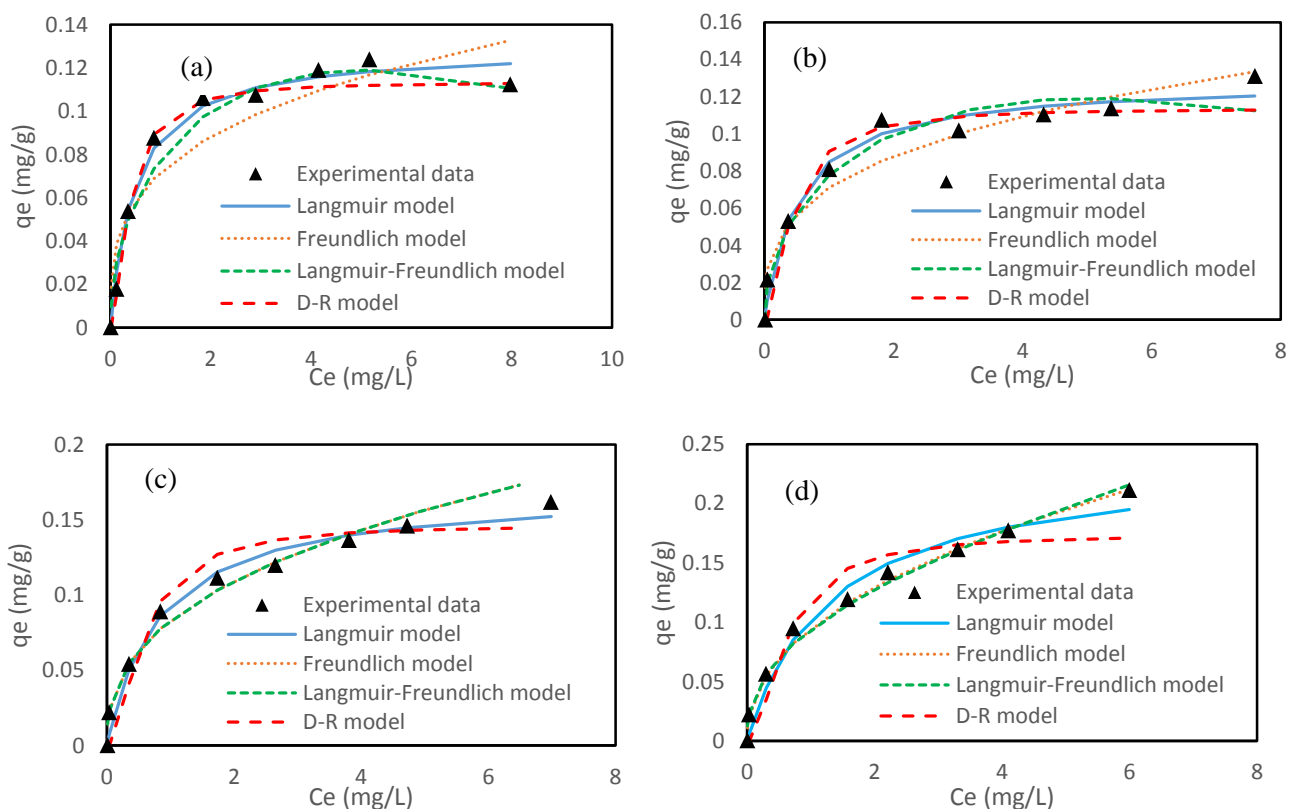
The equilibrium of As (V) adsorption onto DMI-65 best fitted to the Langmuir model ($R^2 > 0.975$) and Langmuir-Freundlich model ($R^2 > 0.940$) for all the pH (5, 6, 7 and 8.5). From Figure 5, it shows that the maximum adsorption capacity for the Langmuir model was found to be 0.237 mg/g at pH 8.5. The adsorption capacity of As (V) onto DMI 65 was the same for pH 5 and 6 at 0.130 mg/g.

Figure 5: *Langmuir adsorption isotherm study of As (V) removal by DMI-65 (adsorbent dosage = 20 g/L, contact time = 24 hours, temperature = 19°C, agitation speed = 130 rpm, pH (5, 6, 7 and 8.5).*
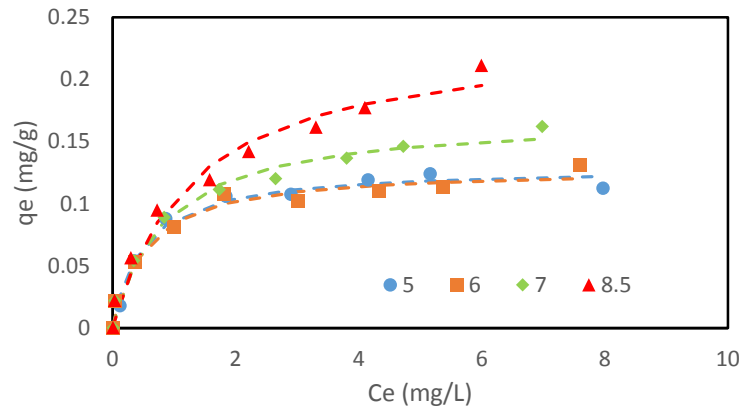
3.3 COLUMN EXPERIMENT

Column experiments were conducted to evaluate the effect of flow rate, pH and initial Arsenic concentration on As (V) removal using DMI-65 in a continuous mode of operation. The DMI 65 was activated before conducting the experiments.

A glass column of 33 mm in diameter and 265 mm in height was filled with 115 g of activated DMI 65 attached to the AKTA Explorer machine. 2 L volume of As (V) solution (0.03 mg/L) was fed through the column in a downward manner and effluent collected at flowrates 5, 10 and 15 ml/min (0.57, 1.14, 1.71 m/hr) from the outlet. As (V) concentrations were analyzed at 0.3 L intervals.

The Thomas model is one of the most widely used models in column performance (Han et al., 2009). The expression used for the Thomas model for an adsorption column is given by Equation (16).

$$\frac{C_t}{C_o} = \frac{1}{1+\exp\left[\left(\frac{k_{Th}q_ex}{Q}\right) - k_{Th}C_o t\right]} \qquad (16)$$

Equation (16) can further be linearized as shown in Equation (17)

$$\ln\left(\frac{C_o}{C_t} - 1\right) = \frac{k_{Th}q_ex}{Q} - k_{Th}C_o t \qquad (17)$$

Where k_{Th} (mL/min.mg) is the Thomas rate constant, q_e (mg/g) is the adsorption capacity of adsorbent, C_o (mg/L) is the initial solution concentration, C_t (mg/L) is the outlet concentration of solution at time t, x (g) is the mass of the adsorbent, Z is the column length and Q is the flowrate (mL/min).

Figure 6: *Linear Thomas kinetic plots, initial As (V) concentration 0.03 mg/L, flow rate (5, 10 and 15 ml/min), (a) pH 6, (b) pH 7 and (c) 8.5*
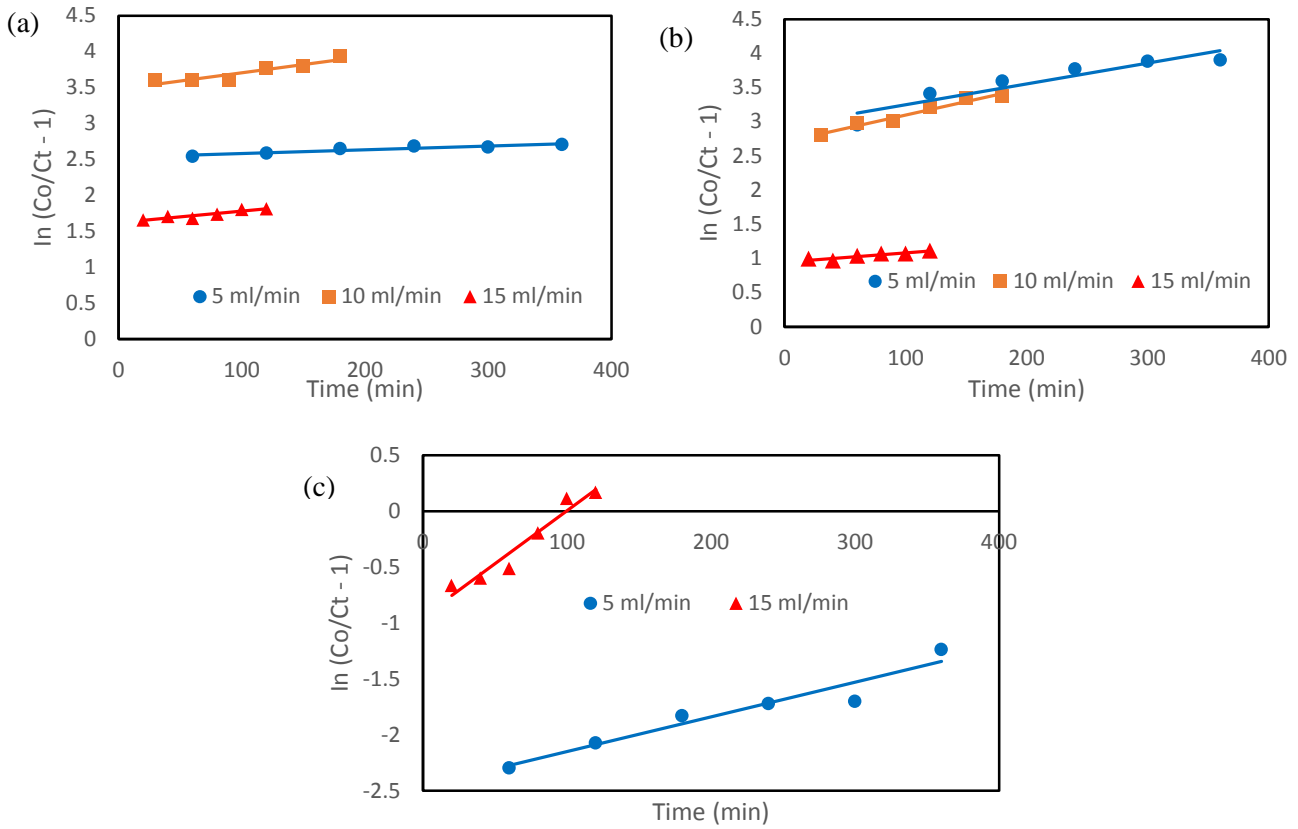
The plot of ln (C_o/C_t − 1) vs t as shown in Figure 6 yielded a straight line which gave k_{Th} and q_e values from the slope and intercept. Other parameters of the Thomas model and values of R^2 as shown in Eq. (17) can be found in Table 3. The column adsorption capacity q_e increases and k_{Th} decreases with increase in flowrate for pH 7 and 8.5. The highest adsorption capacity for the column experiment is 0.005 mg/g at pH 8.5 and flowrate of 15 mL/min.

Table 3: Thomas model parameters for As (V) adsorption under different conditions.

C_o (mg/L)	Q (ml/min)	Z (cm)	pH	k_{Th} (mL/min.mg)	q_e (mg/g)	R^2
0.03	5	26.5	6	97.24	0.000026	0.889
0.03	5	26.5	7	69.12	0.000219	0.880
0.03	5	26.5	8.5	70.10	0.000221	0.929
0.03	10	26.5	6	108.64	0.000212	0.862
0.03	10	26.5	7	63.33	0.000616	0.962
0.03	15	26.5	6	55.36	0.000433	0.876
0.03	15	26.5	7	22.02	0.002043	0.862
0.03	15	26.5	8.5	26.96	0.005282	0.939

The effect of flowrate on As (V) removal at pH 6 shows that 93.7 %, 98.1 % and 85.9 % of As (V) was removed using DMI-65 at 5 mL/min, 10 mL/min and 15 mL/min flowrate respectively. At pH 7, 98 % removal was achieved with flowrate of 5 mL/min after 180

min. The lowest As (V) removal percentage was at pH 8.5 with removal efficiency of 54.3 % at 15 mL/min after 120 min.

Figure 7:   Effect of Flowrate on percentage removal, initial As (V) concentration 0.03 mg/L, flow rate (5, 10 and 15 ml/min), (a) pH 6, (b) pH 7 and (c) 8.5
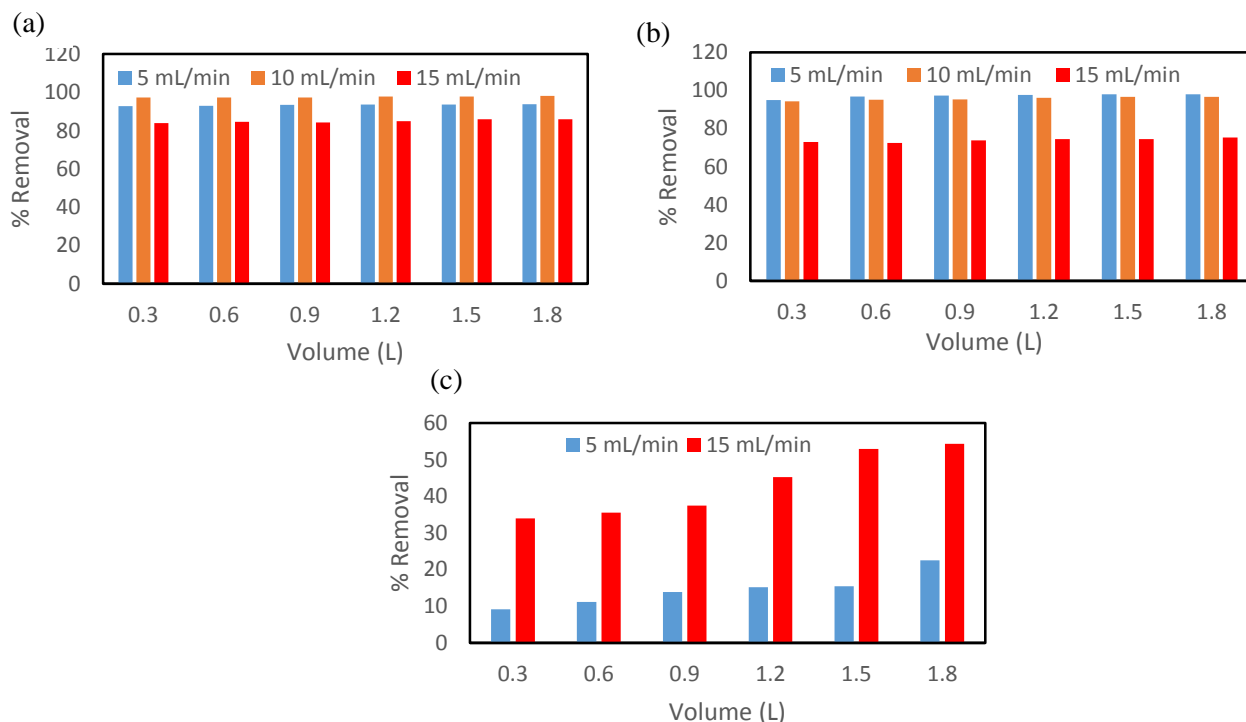
4   CONCLUSIONS

In this study, a silica based catalytic media was assessed for the removal of As (V) using both batch adsorption and column test. The batch adsorption process followed pseudo-second-order kinetics with a correlation coefficient of > 0.999 for all the different pH (5, 6, 7 and 8.5). It took 6 hours for As (V) adsorption onto DMI-65 to reach equilibrium and 90 % of As (V) was removed after contact time of 24 hours at pH 8.5. The adsorption data was best supported by the Langmuir model (R^2 > 0.975) for all the pH investigated in this study. The Langmuir maximum adsorption capacity was found to be 0.237 mg/g at pH 8.5. As (V) removal using DMI-65 in the column experiment was found to be 98.1 % and 98.0 % at pH 6 and pH 7 respectively at 1.14 m/hr. Thus from the results in this investigation, it clearly shows that DMI 65 has great potential in the removal of As (V) from drinking water to less than 10 µg/L, which is the standard set by WHO, US EPA and DWSNZ. Studies on removing As (III) using DMI-65, and studies on using other materials for As (III) and As (V) is currently on-going at the University of Waikato, New Zealand.

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