

## **Supporting Information**

### **Core-shell structured Zero-valent Manganese (ZVM): A novel nanoadsorbent for efficient removal of As(III) and As(V) from drinking water**

Amulya Prasad Panda,<sup>a</sup> Priyanka Rout,<sup>a</sup> Kishore K. Jena,<sup>b</sup> Saeed M. Alhassan,<sup>b</sup> Sanjukta A. Kumar,<sup>c</sup> Usha Jha,<sup>a</sup> R. K. Dey,<sup>d</sup> S. K. Swain<sup>\*e</sup>

<sup>a</sup>Department of Chemistry, Birla Institute of Technology, Mesra, Ranchi, Jharkhand, 835215, India

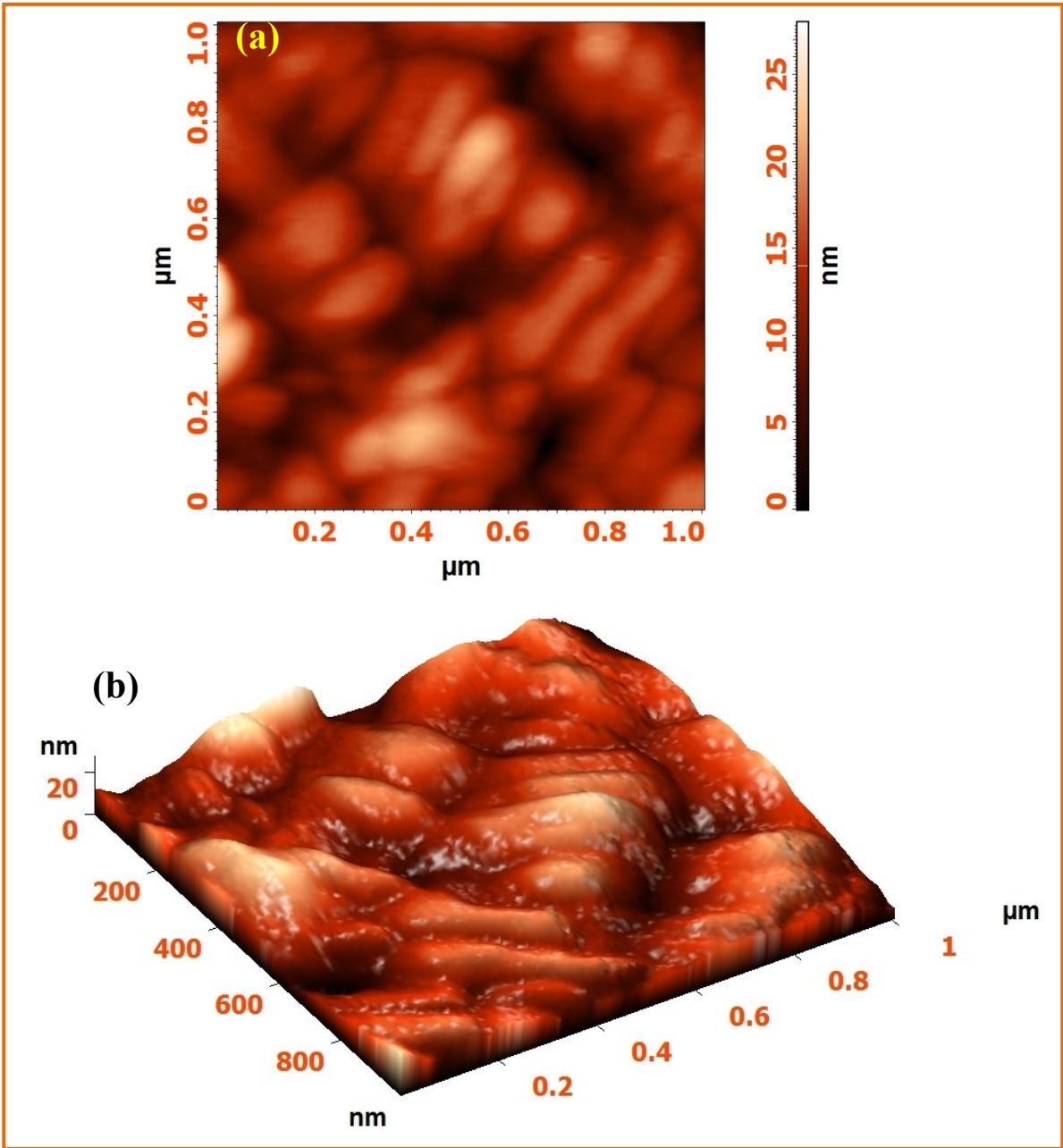
<sup>b</sup>Department of Chemical Engineering, Khalifa University, SAN Campus, Abu Dhabi, 2533, United Arab Emirates (UAE)

<sup>c</sup>Analytical Chemistry Division, Bhabha Atomic Research Centre, Trombay, Mumbai, 400085, India

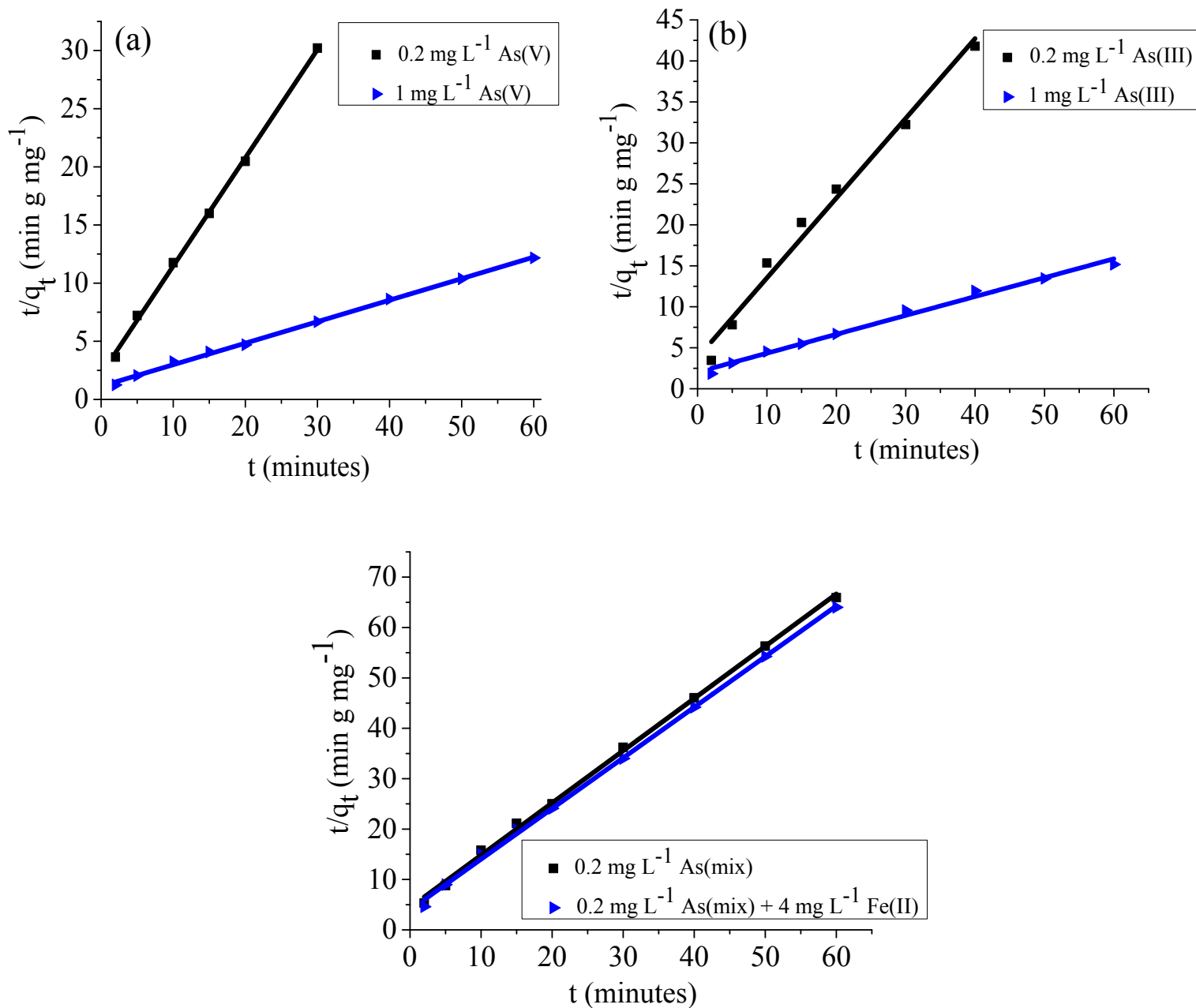
<sup>d</sup>Department of Chemistry, Central University of Jharkhand, Ranchi, Jharkhand, 835205, India

<sup>e</sup>Central Instrumentation Facility, Birla Institute of Technology, Mesra, Ranchi, Jharkhand 835215, India

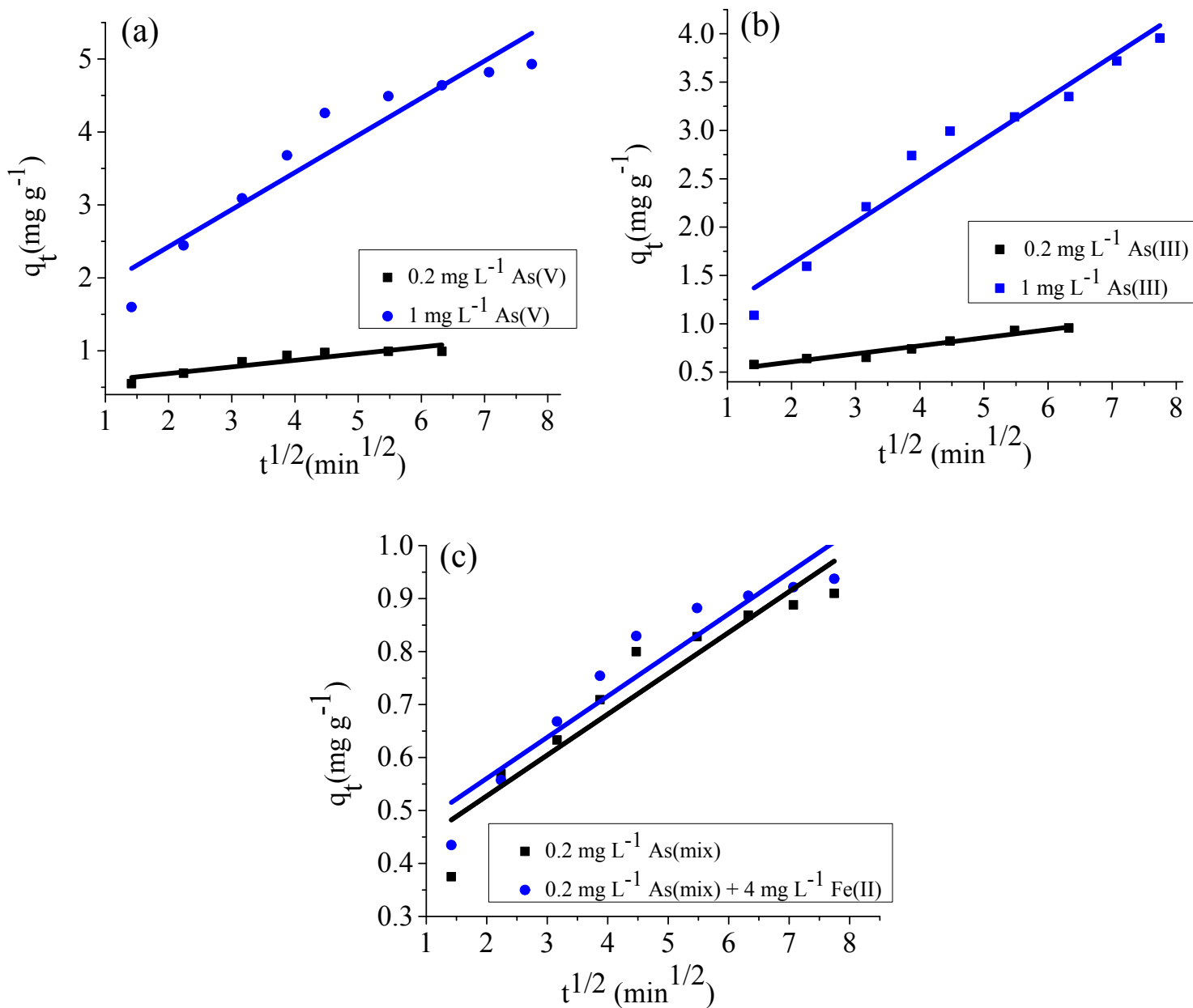
**\*Corresponding Author:** S. K. Swain, E-mail: [skswain@bitmesra.ac.in](mailto:skswain@bitmesra.ac.in), Tel.: +91-9523686103.



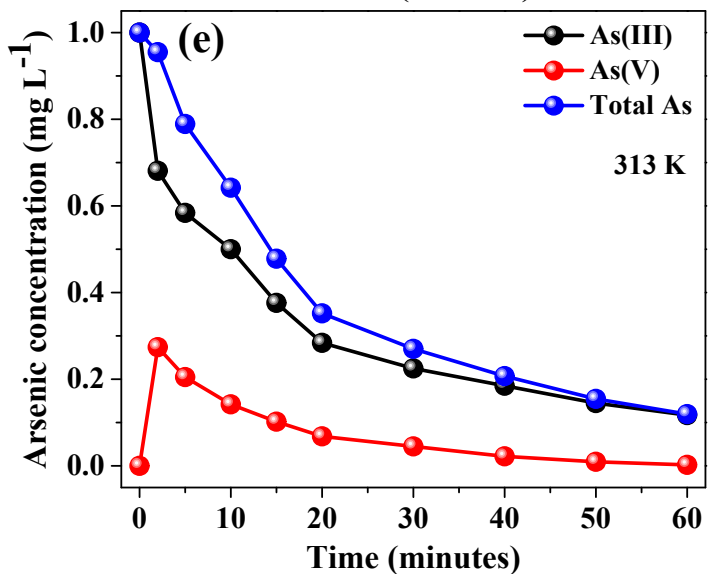
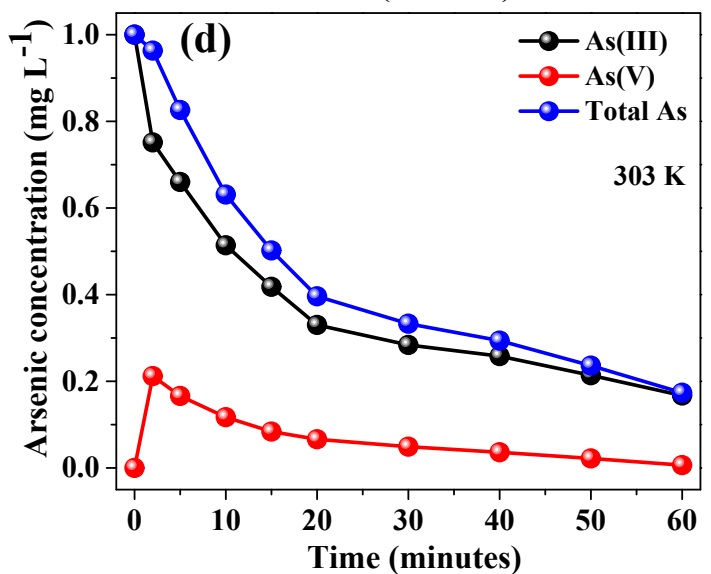
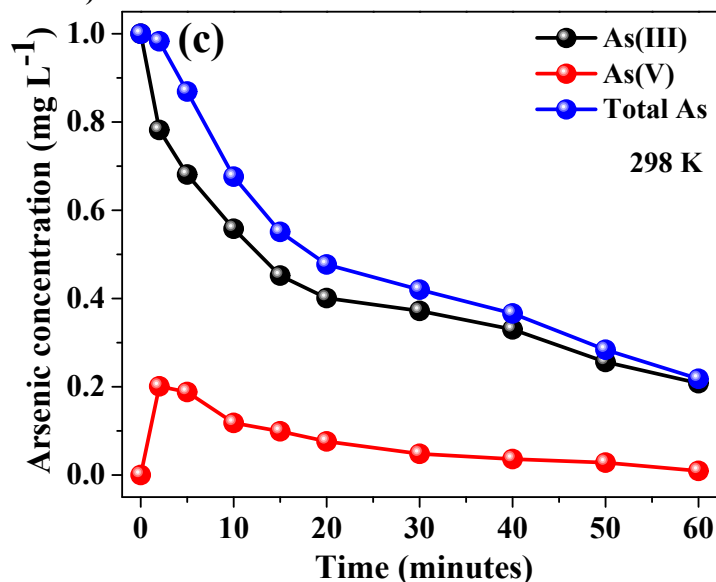
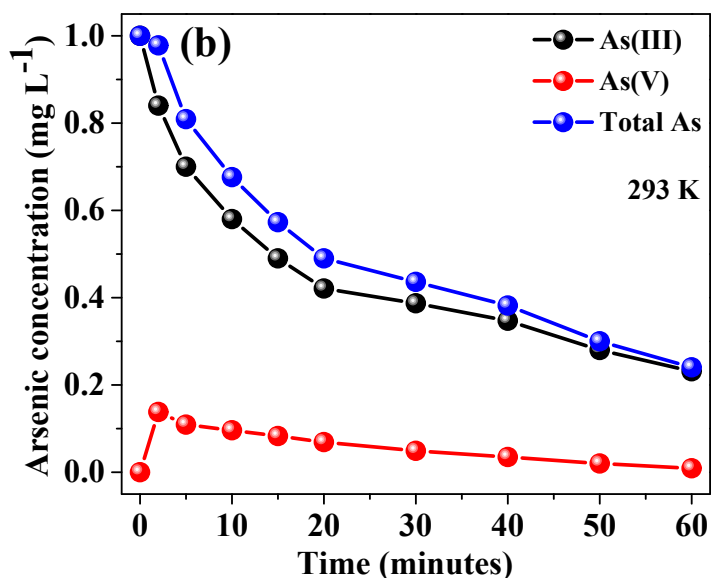
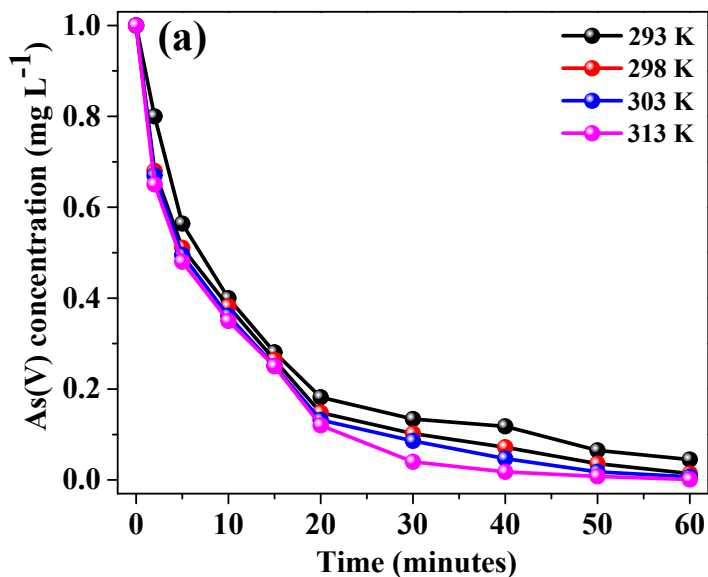
**Fig. S1.** Atomic force microscope image of ZVM surface: (a) 2-D view (b) 3-D view.



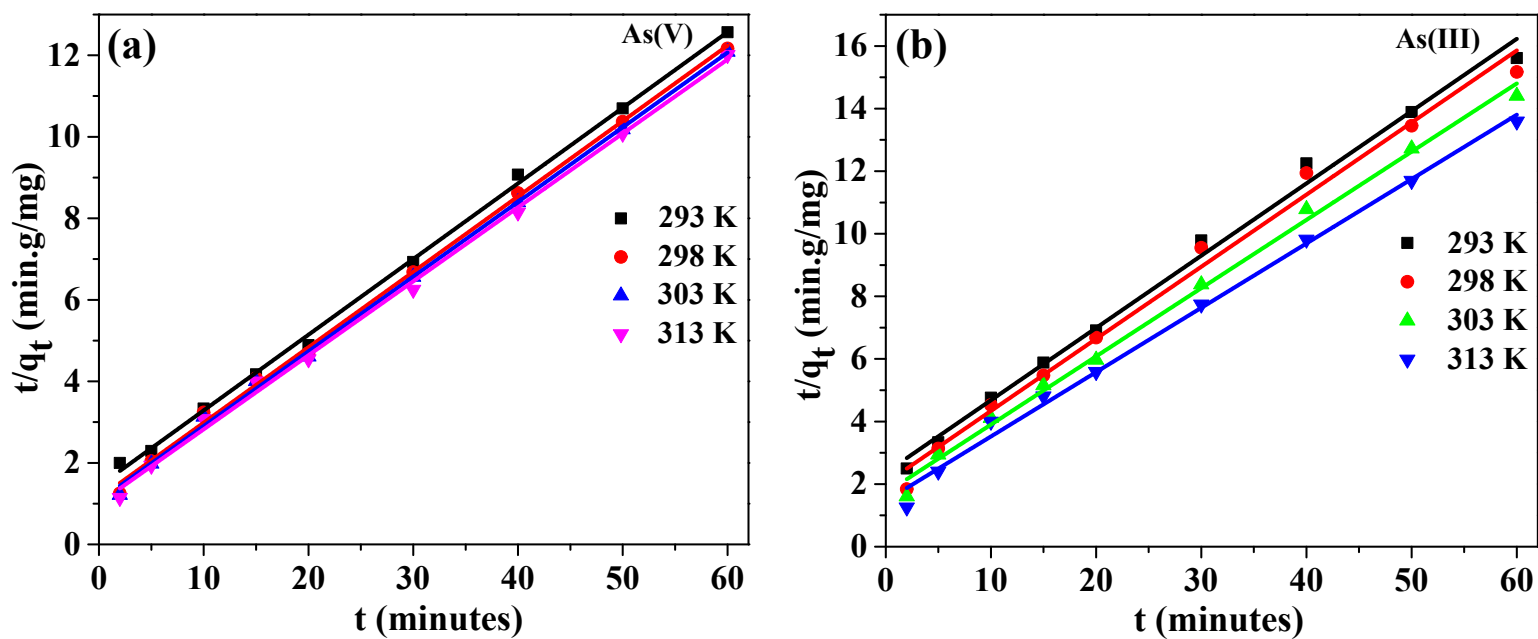
**Fig. S2.** The pseudo-second order kinetic plots for the adsorption of (a) As(V) (0.2 mg L<sup>-1</sup> and 1 mg L<sup>-1</sup>), (b) As(III) (0.2 mg L<sup>-1</sup> and 1 mg L<sup>-1</sup>), (c) As(mix) (0.2 mg L<sup>-1</sup>) and As(mix) (0.2 mg L<sup>-1</sup>) in presence of Fe(II) (4 mg L<sup>-1</sup>) by ZVM. Experimental conditions - adsorbent dose: 0.2 g L<sup>-1</sup>, volume of solution: 50 mL, pH: 6.5 ± 0.2 and temperature: 298 K.



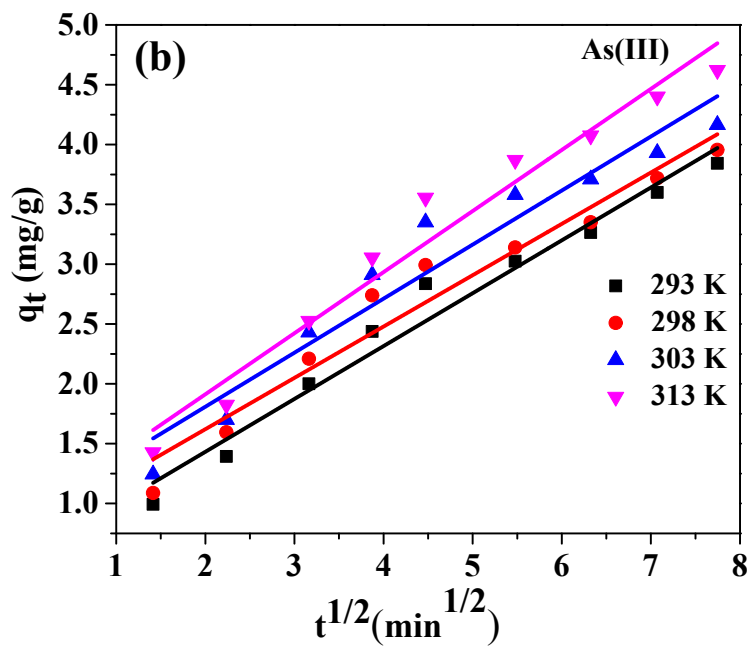
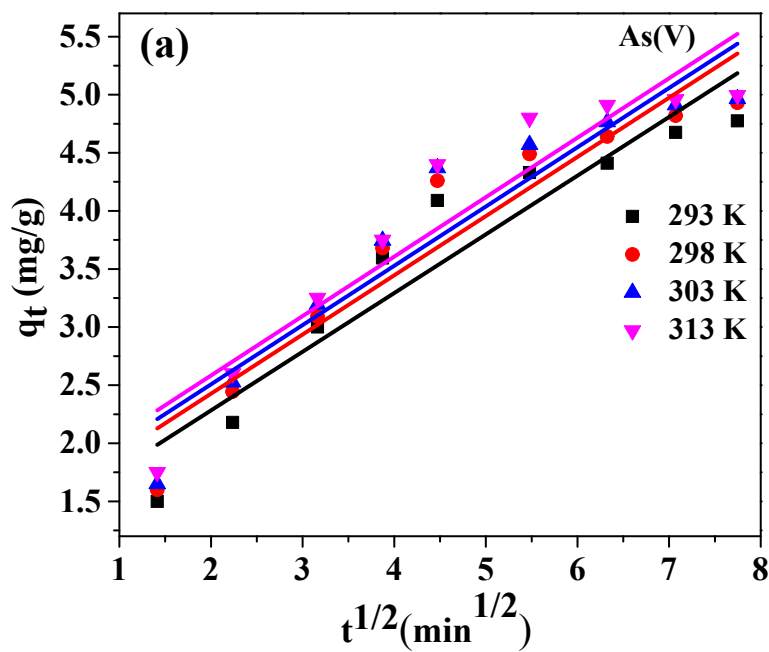
**Fig. S3.** The intra-particle diffusion kinetic plots for the adsorption of (a) As(V) (0.2 mg L<sup>-1</sup> and 1 mg L<sup>-1</sup>), (b) As(III) (0.2 mg L<sup>-1</sup> and 1 mg L<sup>-1</sup>), (c) As(mix) (0.2 mg L<sup>-1</sup>) and As(mix) (0.2 mg L<sup>-1</sup>) in presence of Fe(II) (4 mg L<sup>-1</sup>) by ZVM. Experimental conditions - adsorbent dose: 0.2 g L<sup>-1</sup>, volume of solution: 50 mL, pH: 6.5 ± 0.2 and temperature: 298 K.



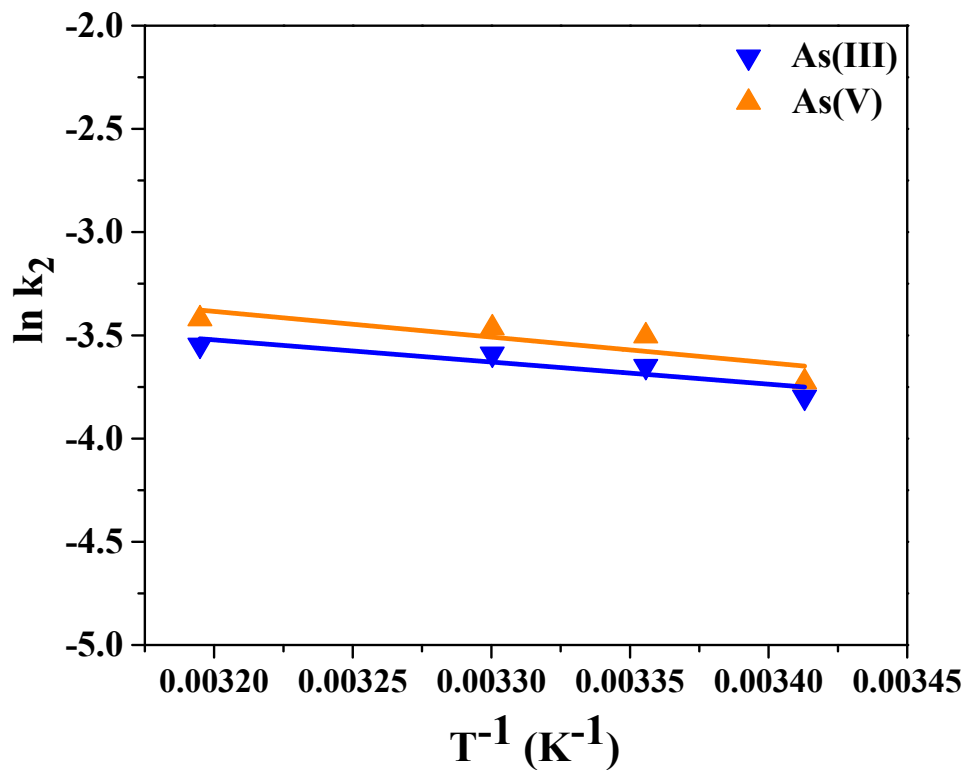
**Fig. S4.** Kinetics of (a) As(V) and (b-e) As(III) adsorption over ZVM at different temperatures. Experimental conditions: adsorbent dose: 0.2 g L<sup>-1</sup>, initial conc. of arsenic: 1 mgL<sup>-1</sup>, volume of solution: 50 mL, pH: 6.5 ± 0.2.



**Fig. S5.** The pseudo-second order kinetic plots for the adsorption of (a) As(V) and (b) As(III) by ZVM at different temperatures. Experimental conditions - adsorbent dose:  $0.2 \text{ g L}^{-1}$ , initial conc. of arsenic:  $1 \text{ mgL}^{-1}$ , volume of solution:  $50 \text{ mL}$ , pH:  $6.5 \pm 0.2$ .

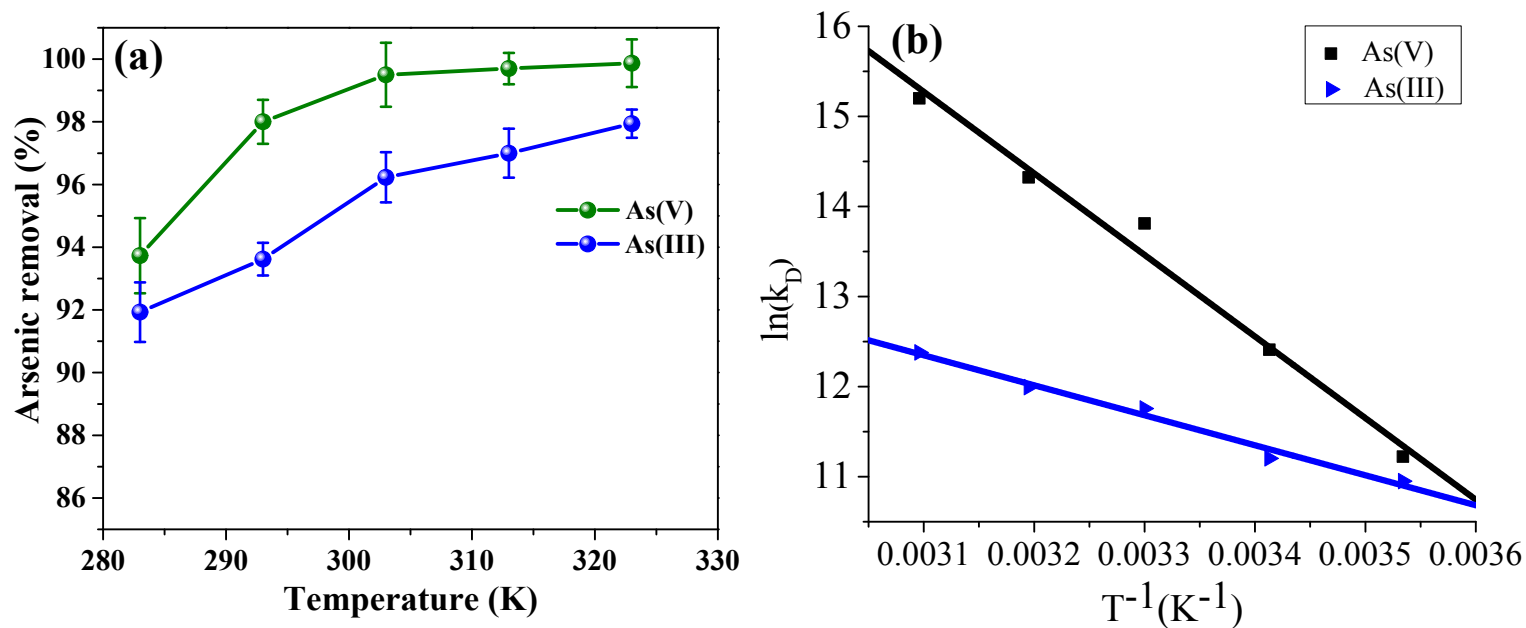


**Fig. S6.** The intra-particle diffusion kinetic plots for the adsorption of (a) As(V) and (b) As(III) by ZVM at different temperatures. Experimental conditions - adsorbent dose:  $0.2 \text{ g L}^{-1}$ , initial conc. of arsenic:  $1 \text{ mgL}^{-1}$ , volume of solution:  $50 \text{ mL}$ ,  $\text{pH}: 6.5 \pm 0.2$ .

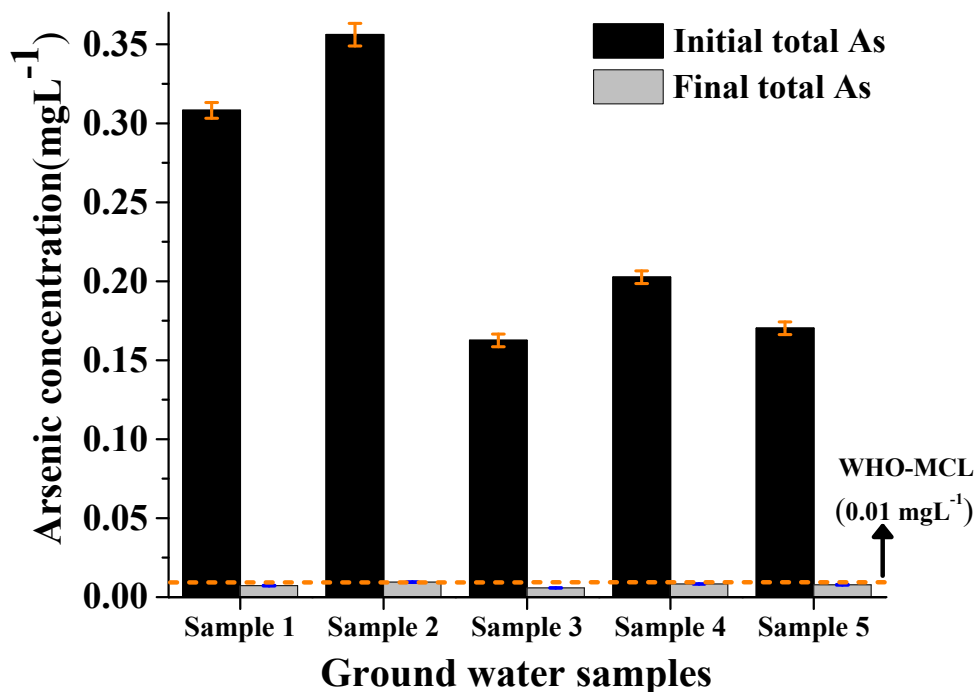


**Fig. S7.** Arrhenius plots for arsenic sorption on ZVM at different temperatures.

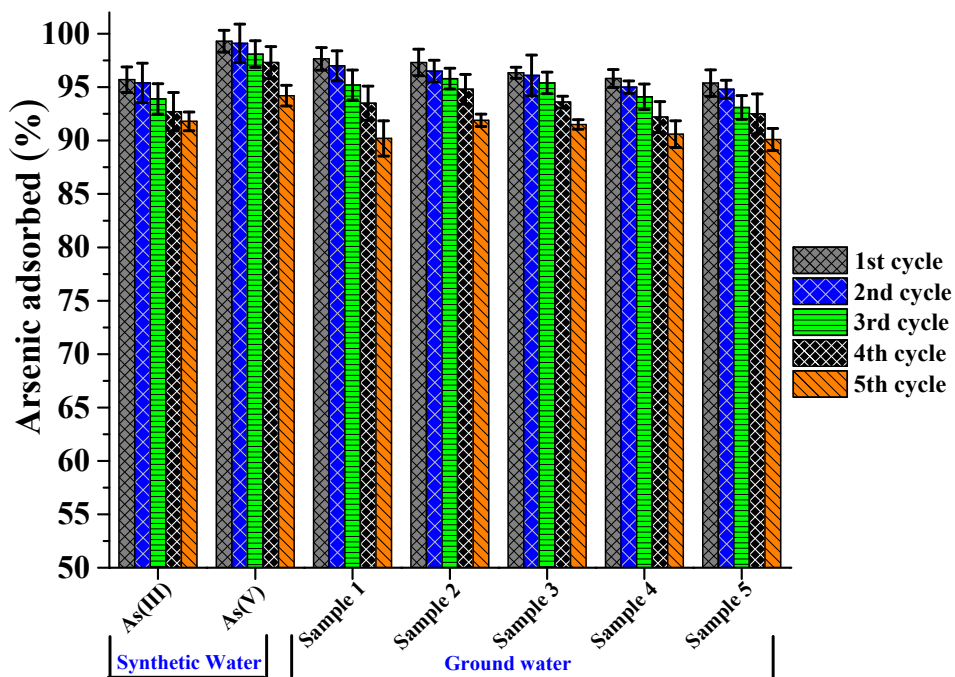




**Fig. S8.** (a) Effect of temperature on adsorption of As(III) and As(V) by ZVM and (b) The corresponding Van't Hoff plot. Experimental conditions – initial concentration of arsenic: 0.2 mg L $^{-1}$ , adsorbent dose: 0.2 g L $^{-1}$ , volume of solution: 50 mL, contact time: 60 minutes and pH: 6.5  $\pm$  0.2.



**Fig. S9.** The arsenic adsorption performance of ZVM with groundwater samples collected from Pathalkudwa Region of Ranchi District, Jharkhand, India. Experimental conditions - adsorbent dose: 0.2 g L<sup>-1</sup>, volume of solution: 50 mL, contact time: 60 minutes and temperature: 298 K.



**Fig. S10.** The reusable efficiency of ZVM with synthetic water and arsenic contaminated ground water after 5 consecutive cycles. Experimental conditions – The initial concentrations of As(III) and As(V): 0.2 mg L<sup>-1</sup>, adsorbent dose: 0.2 g L<sup>-1</sup>, volume of solution: 50 mL, contact time: 60 minutes, and temperature: 298 K.

**Table S1.** The kinetic parameters associated with the adsorptions of different arsenic species of variable concentrations by ZVM.

	Pseudo-first order					Pseudo-second order			Intra-particle diffusion		
	$C_0$ (mg L <sup>-1</sup> )	$q_{e(\text{exp})}$ (mg g <sup>-1</sup> )	$q_{e(\text{cal})}$ (mg g <sup>-1</sup> )	$k_1$ (min <sup>-1</sup> )	$R^2$	$q_{e(\text{cal})}$ (mg g <sup>-1</sup> )	$k_2$ (g mg <sup>-1</sup> min <sup>-1</sup> )	$R^2$	$k_i$ (mg g <sup>-1</sup> min <sup>-1/2</sup> )	$C$ (mg g <sup>-1</sup> )	$R^2$
<b>As(V)</b>	0.2	0.993	0.741	0.182	0.984	1.074	0.400	0.998	0.143	0.367	0.980
	1	4.930	3.450	0.067	0.984	5.400	0.030	0.998	0.509	1.407	0.906
<b>As(III)</b>	0.2	0.957	0.603	0.090	0.887	1.027	0.250	0.985	0.083	0.439	0.960
	1	3.955	2.848	0.045	0.955	4.340	0.026	0.990	0.429	0.762	0.953
<b>As(mix)</b>	0.2	0.909	0.510	0.063	0.986	0.960	0.241	0.998	0.077	0.373	0.896
<b>As(mix) + Fe(II)</b>	0.2	0.937	0.533	0.071	0.994	0.994	0.253	0.998	0.077	0.405	0.905

**Table S2.** The kinetic parameters associated with the adsorptions of As(III) and As(V) by ZVM at different temperatures.

	Pseudo-first order					Pseudo-second order			Intra-particle diffusion			$E_a$ (kJ mol <sup>-1</sup> )	
	$C_0$ (mg L <sup>-1</sup> )	$q_e(\text{exp})$ (mg g <sup>-1</sup> )	$q_e(\text{cal})$ (mg g <sup>-1</sup> )	$k_1$ (min <sup>-1</sup> )	$R^2$	$q_e(\text{cal})$ (mg g <sup>-1</sup> )	$k_2$ (g mg <sup>-1</sup> min <sup>-1</sup> )	$R^2$	$k_i$ (mg g <sup>-1</sup> min <sup>-1/2</sup> )	$C$ (mg g <sup>-1</sup> )	$R^2$		
<b>As(V)</b>	293 K	1	4.775	3.590	0.068	0.964	5.38	0.024	0.998	0.505	1.272	0.872	10.34
	298 K	1	4.930	3.450	0.067	0.984	5.40	0.030	0.998	0.509	1.407	0.906	
	303 K	1	4.965	3.859	0.080	0.986	5.45	0.031	0.998	0.510	1.483	0.901	
	313 K	1	4.995	4.231	0.096	0.994	5.50	0.032	0.997	0.511	1.559	0.894	
<b>As(III)</b>	293 K	1	3.843	2.918	0.046	0.965	4.32	0.022	0.993	0.415	0.554	0.947	8.91
	298 K	1	3.955	2.848	0.045	0.955	4.34	0.026	0.990	0.429	0.762	0.953	
	303 K	1	4.165	2.87	0.050	0.976	4.58	0.027	0.995	0.451	0.905	0.937	
	313 K	1	4.415	3.218	0.060	0.990	4.86	0.028	0.994	0.455	1.167	0.953	

**Table S3.** The thermodynamic parameters associated with the adsorptions of As(V) and As(III) by ZVM.

	Temperature (°C)	$\Delta G^\circ$ (kJ mol <sup>-1</sup> )	$\Delta H^\circ$ (kJ mol <sup>-1</sup> )	$\Delta S^\circ$ (kJ mol <sup>-1</sup> K <sup>-1</sup> )
<b>As(V)</b>	10	-26.692		
	20	-30.297		
	30	-33.902	75.337	0.360
	40	-37.508		
	50	-41.113		
<b>As(III)</b>	10	-25.652		
	20	-27.538		
	30	-29.423	27.708	0.188
	40	-31.309		
	50	-33.194		

**Table S4.** Chemical compositions of collected ground water samples.

	<b>Sample 1</b>	<b>Sample 2</b>	<b>Sample 3</b>	<b>Sample 4</b>	<b>Sample 5</b>
<b>pH</b>	7.13	7.14	6.56	6.94	7.33
<b>Turbidity (NTU)</b>	0.21	0.14	0.01	0.25	0.21
<b>TDS (mg/L)</b>	929	672	683	772	724
<b>Conductivity (<math>\mu\text{S}/\text{cm}</math>)</b>	1896	1372	1394	1575	1477
<b>Total Hardness (mg/L)</b>	700	870	660	690	640
<b>Total Alkalinity (mg/L)</b>	150	155	140	145	170
<b>K (mg/L)</b>	13.04	10.47	9.614	8.824	9.39
<b>Ca (mg/L)</b>	209.64	270.52	191.08	196.48	183.2
<b>Mg (mg/L)</b>	46.04	45.88	43.52	47.28	43.64
<b>Na (mg/L)</b>	167.44	166.04	126.56	158.64	117.28
<b>Fe (mg/L)</b>	0.07	0.02	0.03	0.08	0.05
<b>Mn (mg/L)</b>	0.027	0.047	0.257	0.014	0.031
<b>Zn (mg/L)</b>	0.03	0.029	0.05	0.046	0.12
<b>SO<sub>4</sub><sup>2-</sup> (mg/L)</b>	205.0	160.0	200.0	185.0	120.0
<b>NO<sub>3</sub><sup>-</sup> (mg/L)</b>	35.0	7.8	3.2	31.0	21.0
<b>Cl<sup>-</sup> (mg/L)</b>	259.15	220.1	216.55	259.15	230.75
<b>PO<sub>4</sub><sup>3-</sup> (mg/L)</b>	1.15	1.21	1.10	1.32	0.98
<b>HCO<sub>3</sub><sup>-</sup> (mg/L)</b>	183.0	189.1	170.8	176.9	207.4
<b>F<sup>-</sup> (mg/L)</b>	0.23	0.24	0.27	0.25	0.25
<b>As (mg/L)</b>	0.308	0.356	0.162	0.202	0.170

**Table S5: Comparison of overall arsenic removal efficiency of ZVM with other adsorbents.**

Adsorbent	Experimental Conditions	Batch Adsorption Studies						Remarks	Ref.
		Effect of pH	Kinetic Studies	Isotherm Studies	Effect of interfering anions	Ground water study	Reuse Studies		
<b>HBC-Fe<sub>3</sub>O<sub>4</sub>-MnO<sub>2</sub></b>	<ul style="list-style-type: none"> <li>• <b>Dose:</b> 0.2 g/L</li> <li>• <b>pH:</b> 7.0 ± 0.1</li> <li>• <b>Time:</b> 16 hr</li> <li>• <b>C<sub>0</sub>:</b> 100-800 µg/L As(III/V)</li> <li>• <b>Vol. of Sample:</b> 50 ml</li> <li>• <b>Temperature:</b> 25° C</li> </ul>	<ul style="list-style-type: none"> <li>• Maximum removal observed in acidic pH. However removal efficiency decreased with increase of pH and 40% was obtained at pH 9.0.</li> </ul>	<ul style="list-style-type: none"> <li>• 97% of removal was achieved in 12 hr for initial concentrations of 100 µg/L As(III)/As(V).</li> <li>• Pseudo-second order kinetics</li> </ul>	As(III): q <sub>m</sub> = 2.42 mg/g Freundlich isotherm model As(V): q <sub>m</sub> = 1.45 mg/g Langmuir isotherm model	<ul style="list-style-type: none"> <li>• No significant interference of Cl<sup>-</sup>, SO<sub>4</sub><sup>2-</sup>, NO<sub>3</sub><sup>-</sup>.</li> <li>• Removal efficiency decreased to 25.49% and 13.80% of As(III) and As(V) in presence of 10mM of PO<sub>4</sub><sup>3-</sup>.</li> </ul>	NR	<ul style="list-style-type: none"> <li>• The reusability capacity of the material was reduced to 65.5% after 5<sup>th</sup> cycle of operation with regeneration of adsorbent.</li> </ul>	<ul style="list-style-type: none"> <li>• Less removal in the neutral pH.</li> <li>• Takes extended time of 12 hr to reach equilibrium concentrations</li> <li>• Not effective for successive application in treating higher concentration of arsenic contaminated water.</li> <li>• Pronounced inhibitory effect of HCO<sub>3</sub><sup>-</sup> and PO<sub>4</sub><sup>3-</sup> was witnessed</li> </ul>	<b>S1</b>
<b>Aluminium Oxide/Hydroxide Nanoparticles (AHNP)</b>	<ul style="list-style-type: none"> <li>• <b>Dose:</b> 2 g/L</li> <li>• <b>pH:</b> 7</li> <li>• <b>Time:</b> 300 minutes</li> <li>• <b>C<sub>0</sub>:</b> 100-1000 µg/L</li> <li>• <b>Vol. of Sample:</b> 50 ml</li> <li>• <b>Temperature:</b> 25 °C</li> </ul>	<ul style="list-style-type: none"> <li>• Maximum 85% of removal was observed at pH 7.0 for 500 µg/L of As(III).</li> </ul>	<ul style="list-style-type: none"> <li>• 85% of removal was achieved in 300 minutes for 500 µg/L of arsenic.</li> <li>• Pseudo-second order kinetics</li> </ul>	As(III): q <sub>m</sub> = 0.833 mg/g Langmuir isotherm model As(V): NR	NR	In groundwater, 8g/L of adsorbent was required to reduce the arsenic concentration (512µg/L) below WHO limit in 300 minutes.	NR	<ul style="list-style-type: none"> <li>• Takes extended time of 300 minutes to reach equilibrium that too with high amount of adsorbent (2 g/L).</li> <li>• The maximum removal efficiency of the material was only 85% for 500g/L</li> <li>• Requires higher adsorbent dose to remediate arsenic in groundwater.</li> </ul>	<b>S2</b>
<b>Copper Oxide incorporated mesoporous Alumina (COIMA)</b>	<ul style="list-style-type: none"> <li>• <b>Dose:</b> 0.4 g/L</li> <li>• <b>pH:</b> NR</li> <li>• <b>Time:</b> 24 hr</li> <li>• <b>C<sub>0</sub>:</b> 1 mg/L</li> <li>• <b>Vol. of Sample:</b> 50 ml</li> <li>• <b>Temperature:</b> 30 ±1 °C</li> </ul>	<ul style="list-style-type: none"> <li>• Maximum removal observed in acidic pH.</li> <li>• At neutral pH the removal of As(V) is around 75% and that of As(III) is around 85%.</li> </ul>	<ul style="list-style-type: none"> <li>• Adsorption equilibrium achieved in 500 minutes.</li> </ul>	As(III): q <sub>m</sub> = 2.161 mg/g Langmuir isotherm model As(V): q <sub>m</sub> = 2.017 mg/g Langmuir isotherm model	In presence of coexisting anions (PO <sub>4</sub> <sup>3-</sup> , SO <sub>4</sub> <sup>2-</sup> , NO <sub>3</sub> <sup>-</sup> , HCO <sub>3</sub> <sup>-</sup> , CO <sub>3</sub> <sup>2-</sup> ), As(V) uptake reduced considerably while As(III) removal efficiency decreased to 80% .	NR	Adsorption capacity remains constant after fourth cycles of regeneration and reuse.	<ul style="list-style-type: none"> <li>• Less effective at neutral pH.</li> <li>• Negative effect of coexisting anions in As(V) uptake.</li> <li>• Required high reaction time to reach equilibrium.</li> </ul>	<b>S3</b>

<b>FeOOH/ <math>\gamma</math>-<math>\text{Al}_2\text{O}_3</math></b>	<ul style="list-style-type: none"> <li>• <b>Dose:</b> 5 g/L</li> <li>• <b>pH:</b> Natural pH</li> <li>• <b>Time:</b> 60 minutes</li> <li>• <b><math>C_0</math>:</b> 10-100 mg/L</li> <li>• <b>Vol. of Sample:</b> 220 ml</li> <li>• <b>Temperature:</b> 25 °C</li> </ul>	<ul style="list-style-type: none"> <li>• Maximum removal observed in neutral pH but the final arsenic concentration does not meet the WHO standard.</li> <li>• The final pH of the solution reduces to 4.0.</li> </ul>	<ul style="list-style-type: none"> <li>• Adsorption equilibrium achieved in 60 minutes for initial concentration of 10 mg/L arsenic.</li> <li>• Pseudo-second order kinetics.</li> </ul>	As(III): NR  As(V): $q_m = 3,541$ mg/g Langmuir isotherm model	The presence of $\text{SO}_4^{2-}$ , $\text{Cl}^-$ and $\text{NO}_3^-$ had significant negative effects on As(III) adsorption.	NR	NR	<ul style="list-style-type: none"> <li>• Requires higher adsorbent dose.</li> <li>• The pH of the final solution decreases to 4.0.</li> <li>• Final arsenic concentration does not meet the WHO standard.</li> </ul>	<b>S4</b>
<b>Porous <math>\text{Fe}_3\text{O}_4</math> Particles</b>	<ul style="list-style-type: none"> <li>• <b>Dose:</b> 0.5 g/L</li> <li>• <b>pH:</b> <math>5.0 \pm 0.2</math></li> <li>• <b>Time:</b> 4 hr</li> <li>• <b><math>C_0</math>:</b> 0.1-17 mg/L for As(III) and 0.1-7.5 mg/L for As(V)</li> <li>• <b>Vol. of Sample:</b> 10 ml</li> <li>• <b>Temperature:</b> 25 °C</li> </ul>	<ul style="list-style-type: none"> <li>• Adsorption studies conducted at pH 5.0.</li> </ul>	<ul style="list-style-type: none"> <li>• Maximum removal of 90.7% for As(V) and 88.3% for As(III) was achieved in 4 hr for initial concentration of 3 mg/L of As(III) and 3.5 mg/L of As(V).</li> <li>• Pseudo-second order kinetics.</li> </ul>	As(III): 6.06 mg/L Freundlich Isotherm  As(V): $q_m = 6.35$ mg/L Langmuir Isotherm	NR	NR	The reusability capacity of the material was reduced to 85% after 5 <sup>th</sup> cycle of operation with regeneration of adsorbent.	<ul style="list-style-type: none"> <li>• Batch experiments conducted at acidic pH which does not fall under the pH range of drinking water.</li> <li>• Shows only 85% of arsenic removal even after regeneration.</li> </ul>	<b>S5</b>
<b>Fe-MWCNT</b>	<ul style="list-style-type: none"> <li>• <b>Dose:</b> 1 g/L</li> <li>• <b>pH:</b> 4</li> <li>• <b>Time:</b> 1 hr for As(V) and 12 hr for As(III)</li> <li>• <b><math>C_0</math>:</b> 0.1 mg/L</li> <li>• <b>Vol. of Sample:</b> 10 ml</li> <li>• <b>Temperature:</b> 28-40°C</li> </ul>	<ul style="list-style-type: none"> <li>• Maximum removal for As(V) was observed at pH 4.0 and for As(III) at pH 5.0.</li> </ul>	<ul style="list-style-type: none"> <li>• 99 % of As(V) and 80 % of As(III) were removed in 30 minutes for 100 <math>\mu\text{g/L}</math> of arsenic at pH 4.0.</li> <li>• Pseudo-second order kinetics.</li> </ul>	As(III): $q_m = 1.723$ mg/g Freundlich isotherm model  As(V): $q_m = 0.189$ mg/g Freundlich isotherm model	NR	NR	NR	<ul style="list-style-type: none"> <li>• Batch experiments conducted at pH 4 which does not fall under the pH range of drinking water.</li> <li>• Other important adsorption parameters were not studied</li> </ul>	<b>S6</b>
<b>Copper (II) Oxide</b>	<ul style="list-style-type: none"> <li>• <b>Dose:</b> 1 g/L</li> <li>• <b>pH:</b> 7</li> <li>• <b>Time:</b> 24 hr</li> <li>• <b><math>C_0</math>:</b> 0.5-1 mg/L</li> <li>• <b>Vol. of Sample:</b> 100 ml</li> <li>• <b>Temperature:</b> <math>25 \pm 2^\circ\text{C}</math></li> </ul>	<ul style="list-style-type: none"> <li>• 100% arsenic was removed from water at pH above 8.0 while removal percentage decreased to 75% in acidic pH.</li> </ul>	<ul style="list-style-type: none"> <li>• 92% removal of As(III) was achieved for initial concentration of 1000 <math>\mu\text{g/L}</math> and 100% removal achieved for 200 <math>\mu\text{g/L}</math> initial arsenic concentration in 3 hr.</li> <li>• Pseudo-second order kinetics.</li> </ul>	As(III): $q_m = 1.086$ mg/g Langmuir isotherm model  As(V): NR	<ul style="list-style-type: none"> <li>• The presence of <math>\text{SO}_4^{2-}</math> at very high concentrations (280 mg/L) decreased the arsenic removal percentage by less than 10%.</li> <li>• More than 20% decrease in arsenic removal was observed for greater <math>\text{PO}_4^{3-}</math> concentrations (0.2 mM).</li> </ul>	NR	<ul style="list-style-type: none"> <li>• 4% decrease in adsorption efficiency was observed with regenerated adsorbents (for 100 <math>\mu\text{g/L}</math> of arsenic at adsorbent dose of 1 g/L with 3hr of contact time)</li> </ul>	<ul style="list-style-type: none"> <li>• Requires extended time of 3 hr to achieve 92% removal for 1 mg/L As(III) concentration.</li> <li>• Less selectivity of adsorbent for arsenic in presence of <math>\text{PO}_4^{3-}</math> (0.2mM).</li> <li>• Adsorption capacity of the adsorbent is very less.</li> </ul>	<b>S7</b>



<b>FeMn-synergetic adsorbent</b>	<ul style="list-style-type: none"> <li>• <b>Dose:</b> 2 g/L</li> <li>• <b>pH:</b> 3.5 ± 0.1</li> <li>• <b>Time:</b> 24 hr.</li> <li>• <b>C<sub>0</sub>:</b> 0.45 mg/L</li> <li>• <b>Vol. of Sample:</b> NR</li> <li>• <b>Temperature:</b> 298 K</li> </ul>	Adsorption studies conducted at 3.5.	<ul style="list-style-type: none"> <li>• 95% removal of As(III) was achieved in 1hr for initial concentration of 0.45 mg/L.</li> <li>• Pseudo-second order kinetics</li> </ul>	As(III): $q_m = 10.55$ mg/g Langmuir isotherm model As(V): NR	<ul style="list-style-type: none"> <li>• Cl<sup>-</sup>, NO<sub>3</sub><sup>-</sup> and SO<sub>4</sub><sup>2-</sup> had negligible influence on As(III) removal, while the effect of PO<sub>4</sub><sup>3-</sup> and SiO<sub>3</sub><sup>2-</sup> was more pronounced.</li> </ul>	NR	<ul style="list-style-type: none"> <li>• The removal percentages were maintained at nearly 100% during the five cycles with regeneration of adsorbent.</li> </ul>	<ul style="list-style-type: none"> <li>• Batch experiments conducted at pH 3.5 which does not fall under the pH range of drinking water.</li> <li>• Requirement of higher adsorbent dose for low arsenic concentration to reach equilibrium.</li> <li>• The efficiency of adsorbent was not examined for real groundwater.</li> </ul>	<b>S8</b>
<b>Nanoscale Zero valent iron (NZVI)</b>	<ul style="list-style-type: none"> <li>• <b>Dose:</b> 1 g/L</li> <li>• <b>pH:</b> 7</li> <li>• <b>Time:</b> 12 hr</li> <li>• <b>C<sub>0</sub>:</b> 1 mg/L of As(III) in 0.01 M NaCl</li> <li>• <b>Vol. of Sample:</b> 20 ml</li> <li>• <b>Temperature:</b> 25° C</li> </ul>	<ul style="list-style-type: none"> <li>• 88.6-99.9% removal of As(III) was achieved in pH range 4-10.</li> </ul>	<ul style="list-style-type: none"> <li>• 80% of As(III) was removed in 7 minutes for initial concentration of 1 mg/L arsenic.</li> <li>• Pseudo-second order kinetics.</li> </ul>	As(III): $q_m = 3.5$ mg/g Freundlich isotherm model As(V): NR	<ul style="list-style-type: none"> <li>• No effect of HCO<sub>3</sub><sup>-</sup>, SO<sub>4</sub><sup>2-</sup> and NO<sub>3</sub><sup>-</sup>.</li> <li>• However the presence of 10mM of SiO<sub>4</sub><sup>4-</sup> and PO<sub>4</sub><sup>3-</sup> reduced As(III) uptake from 99.9 % to 44.94 % and 66.3%</li> </ul>	100% removal efficiency was achieved with 1.0-4.5 g/L of NZVI.	NR	<ul style="list-style-type: none"> <li>• Requirement of greater amount of adsorbent dose for complete removal of As(III) in ground water environment.</li> </ul>	<b>S9</b>
<b>Zero-valent Manganese (ZVM)</b>	<ul style="list-style-type: none"> <li>• <b>Dose:</b> 0.2 g/L</li> <li>• <b>pH:</b> 6.5 ± 0.2</li> <li>• <b>Time:</b> 1 hr.</li> <li>• <b>C<sub>0</sub>:</b> 0.1-50 mg/L</li> <li>• <b>Vol. of Sample:</b> 50 ml</li> <li>• <b>Temperature:</b> 25° C</li> </ul>	<ul style="list-style-type: none"> <li>• More than 90% removal was achieved in a wide pH range (3.0-9.0) for both As(III) and As(V).</li> <li>• In neutral pH range, material is capable to reduce the arsenic concentration below WHO limit.</li> </ul>	<ul style="list-style-type: none"> <li>• Removal of 95.7% and 99.9% was achieved for 0.2 mg/L and 1 mg/L of As(V) in 30 minutes and 1 hr.</li> <li>• 99.31% and 89.2% of As(III) was removed for 0.2 mg/L and 1 mg/L of As(III) in 30 minutes and 1 hr. respectively.</li> <li>• The presence of Fe(II) enhanced arsenic removal efficiency to 95.24% and 99% in 1 hr compared to the removal achieved in As(mix) solution.</li> <li>• Pseudo-second order kinetics</li> </ul>	As(III): $q_m = 30.9$ mg/g DR isotherm As(V): $q_m = 72.5$ mg/g DR isotherm	<ul style="list-style-type: none"> <li>• No major influence of Cl<sup>-</sup>, NO<sub>3</sub><sup>-</sup>, SO<sub>4</sub><sup>2-</sup>.</li> <li>• Higher selectivity of ZVM for arsenic over phosphate even at high concentrations. (As:PO<sub>4</sub><sup>3-</sup> = 1:1,1:5,5:1)</li> </ul>	Arsenic was removed below WHO-MCL limit in all groundwater samples.	Even after 5 <sup>th</sup> cycle, adsorbent exhibits removal efficiency of 91.8% for As(III) and 94.2% for As(V).	<ul style="list-style-type: none"> <li>• Provides single step treatment option for total arsenic without any pretreatment.</li> <li>• Material exhibits faster kinetics for both As(III) and As(V).</li> <li>• Material shows high reuse capacity.</li> <li>• Material was efficient enough to remediate total arsenic below the WHO-MCL in ground water environment.</li> </ul>	<b>Our Work</b>

\*NR: Not Reported

## References:

- S1 J. Zhu, S. A. Baig, T. Sheng, Z. Lou, Z. Wang and X. Xu, *J. Hazard. Mater.*, 2015, **286**, 220–228.
- S2 V. K. Rathore and P. Mondal, *Ind. Eng. Chem. Res.*, 2017, **56**, 8081-8094.
- S3 P. Pillewan, S. Mukherjee, T. Roychowdhury, S. Das, A. Bansiwala and S. Rayalu, *J. Hazard. Mater.*, 2011, **186**, 367–375.
- S4 Z. Wang, X. Shen, M. Jing and C. Li, *J. Alloys Compd.*, 2018, **735**, 1620–1628.
- S5 T. Wang, L. Zhang, H. Wang, W. Yang, Y. Fu, W. Zhou, W. Yu, K. Xiang, Z. Su, S. Dai and L. Chai, *ACS Appl. Mater. Interfaces*, 2013, **5**, 23, 12449-12459.
- S6 S. A. Ntim and S. Mitra, *J. Chem. Eng. Data*, 2011, **56**, 2077–2083.
- S7 A. Goswami, P. K. Raul and M. K. Purkait, *Chem. Eng. Res. Des.*, 2012, **90**, 1387-1396.
- S8 B. Zhi, H. Ding, D. Wang, Y. Cao, Y. Zhang, X. Wang, Y. Liu and Q. Huo, *J. Mater. Chem. A*, 2014, **2**, 2374–2382.
- S9 S. R. Kanel, and B. Manning, L. Charlet and H. Choi, *Environ. Sci. Technol.*, 2005, **39**, 1291–1298.