SUPPORTING INFORMATION

Arsenic(V) biosorption by charred orange peel in aqueous environments

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Figure S1 Effect of contact time on the sorption of As(V) by charred orange peel (COP) and natural orange peel (NOP), at an initial As concentration of 200 mg L⁻¹ at pH 6.5 and 20 °C (error bars are standard error of the mean value of 3 replicates).

Figure S2 Effect of biosorbent dose (1–20 g L⁻¹) on the As(V) sorption capacity of charred orange peel (COP) and natural orange peel (NOP), at an initial As(V) concentration of 200 mg L⁻¹ at pH 6.5 and 20 °C. Data are presented as mean ± standard error of 3 replicates.

Figure S3 (a) Freundlich; (b) Langmuir; (c) Dubinin–Radushkevich; (d) Temkin sorption isotherms of As by charred orange peel (COP) and natural orange peel (NOP) at 4 g L⁻¹ biosorbent dose, pH 6.5 and at 20 °C. The dotted (---) and solid (—) lines represent the model fits of the experimental data for COP and NOP, respectively.

Figure S4 Relationship between initial As(V) concentration (0.1–250 mg L⁻¹) in aqueous solutions and separation factor (R_L) obtained from Langmuir isotherm model of charred orange peel (COP) and natural orange peel (NOP) at 20 °C and at pH 6.5.

Figure S5 FTIR transmittance spectra of charred orange peel (COP) (a) no As(V) loading, (c) As(V) loading; and natural orange peel (NOP) (b) no As(V) loading, and (d) As(V) loading.

(a) COP - no As loading

(b) COP - As loaded

Figure S6 Scanning electron microphotographs of charred orange peel (COP) with (a) no As(V) loading, and (b) As(V) loading.

(a) NOP - no As loading

(b) NOP - As loaded

Figure S7 Scanning electron microphotographs of natural orange peel (NOP) with (a) no As(V) loading, and (b) As(V) loading.

(a) COP – As loaded

Element	Wt. %
C	26.54
Mg	0.03
Al	0.02
Ca	0.17
S	0.94
As	0.07
O	72.23

(b) NOP – As loaded

Element	Wt. %
C	26.76
Mg	0.04
Al	0.03
Ca	0.52
S	Not detected
As	0.03
O	71.77

Energy (keV)

Figure S8 Elemental distribution determined using scanning electron microscopy combined with energy dispersive X-ray spectroscopy (SEM-EDX) for As(V) loaded (a) charred orange peel (COP) and (b) natural orange peel (NOP).

Table S1 Arsenic sorption capacity of various biosorbents at optimum pH in batch systems.

Biosorbents	Optimum pH	Maximum sorption capacity (mg g ⁻¹)	Reference
Coconut shell	10	0.37 (As(III))	(Pino <i>et al.</i> , 2006)
Coconut coir pith	7	13.57 (As(V))	(Anirudhan and Unnithan, 2007)
Pine leaves	4	3.27 (As(V))	(Shafique <i>et al.</i> , 2012)
Coconut-shell carbon	5	2.4 (As(V))	(Sathish <i>et al.</i> , 2007)
Rice polish	4	0.14 (As(V))	(Ranjan <i>et al.</i> , 2009)
Rice husk (Iron treated)	4	0.033 (As(V))	(Mohan <i>et al.</i> , 2007)
Fe-modified bamboo charcoal	4-5 3-4	7.23 (As(III)) 19.77 (As(V))	(Khan <i>et al.</i> , 2008)
Magnetic (Fe ₃ O ₄) wheat straw	7-9	3.8 (As(III))	(Tian <i>et al.</i> , 2011)
Tea waste	6	2.22 (As(V))	(Yadanaparthi <i>et al.</i> , 2009)
Activated carbon from <i>Moringa oleifera</i> leaves	7	6.23 (As(V))	(Sumathi and Alagumuthu, 2014)
Ca(OH) ₂ treated orange peel	7	43.7 (As(V))	(Peng <i>et al.</i> , 2013)
Charred orange peel (COP)	6.5	60.9 (As(V))	Present study
Natural orange peel (NOP)	6.5	32.7 (As(V))	Present study

Arsenate analysis in water using molybdene blue method

Preparation of reagents for As(V) determination

The ammonium molybdate tetrahydrate (13 % wt/vol; 100 mL, $(\text{NH}_4)_6\text{Mo}_7\text{O}_{24}\cdot 4\text{H}_2\text{O}$) and potassium antimony tartrate (0.35 % wt/vol; 100 mL, $\text{K}(\text{SbO})\text{C}_4\text{H}_4\text{O}_6\cdot 1/2 \text{H}_2\text{O}$) solutions were mixed with 9 M H_2SO_4 and the final volume was made up to 500 mL. This reagent is known as ‘‘reagent A’’ (Lenoble et al., 2003). Another solution of ascorbic acid (10 % wt/vol, $\text{C}_6\text{H}_8\text{O}_6$) was freshly prepared before use for As(V) analysis.

Sorption isotherm models

The two parameter-based sorption isotherm models were used to evaluate the sorption mechanism of As(V) on the surface of COP and NOP. The four models are Freundlich, Langmuir, Temkin, and Dubinin–Radushkevich (Ahmad et al. 2013).

The linear form of Freundlich model was employed that describes the sorption of the sorbate (As) on heterogeneous as well as on the multilayer surfaces (Eq 1):

$$\ln q_e = \ln q_f + 1/n \ln C_e \quad (1)$$

Where, q_e is the As sorbed per unit mass of the biosorbent (mg g^{-1}), q_f is the relative sorption capacity (mg g^{-1}), n is a parameter related to linearity, and C_e is equilibrium As(V) concentration in the solution (mg L^{-1}).

The sorption on planar surfaces and monolayer adsorption are described by the Langmuir model; the linear form of the Langmuir model is as follows (Eq. 2) (Bibi et al. 2014):

$$1/q_e = 1/q_L + 1/K_L q_L C_e \quad (2)$$

where, q_e is As(V) sorption in equilibrium (mg g^{-1}), q_L is the maximum monolayer covering capacity (mg g^{-1}), K_L is the isotherm constant (L mg^{-1}), C_e is equilibrium

As(V) concentration in the solution (mg L^{-1}). The essential features of the Langmuir model were expressed in terms of a separation factor (R_L) to determine whether the sorption system was favorable or unfavorable in batch experiments, and is given by Eq. 3:

$$R_L = 1/(1 + K_L C_o) \quad (3)$$

The Temkin model was related to the heat of sorption and it is expressed as follows (Eq. 4):

$$q_e = (RT/b_T) \ln A_T + (RT/b) \ln C_e \quad (4)$$

where, R is the universal gas constant ($8.314 \text{ J mol}^{-1} \text{ K}^{-1}$), T is absolute temperature (298K), b_T is isotherm constant, A_T is the Temkin isotherm equilibrium binding constant (L mg^{-1}), and $RT/b_T = B$, which is constant related to the heat of sorption (J mol^{-1}).

The Dubinin-Radushkevich model describing sorption onto porous structure of the sorbent is given by Eq. 5:

$$\ln q_e = \ln(q_D) - K_{ad} \mathcal{E}^2 \quad (5)$$

where, q_D is the sorption capacity (mg g^{-1}); K_{ad} is Dubinin-Radushkevich isotherm constant ($\text{mol}^2 \text{ kJ}^{-2}$); R and T are the universal gas constant and absolute temperature, respectively; $\mathcal{E}$ (Polanyi) is the sorption potential, which is the amount of energy required to pull a sorbed molecule or ion from its sorption site (Shan et al., 2012). The $\mathcal{E}$ can be calculated as follows (Eq. 6):

$$\mathcal{E} = RT \ln(1 + 1/C_e) \quad (6)$$

The bonding energy (E) for the ion-exchange mechanism is calculated using the following relationship (Eq. 7) (Ahmad et al. 2013):

$$E = 1/(2B_D)^{0.5} \quad (7)$$

B_D is the mean free energy of sorption and it is calculated as follows (Eq. 8), using the slope value obtained from the linear regression equation of the Dubinin-Radushkevich model:

$$B_D = \text{Slope}/R^2T^2 \quad (8)$$

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