Supplemental information

Initial estimates for the film mass transport coefficient (k_f) were based on the Gnielinski correlation [23]:

$$k_f = \frac{[1+1.5(1-\varepsilon)]\times D_l}{d_p} \times \left(2 + 0.644 \times \mathrm{Re}^{1/2} \times \mathrm{Sc}^{1/3}\right) \quad \text{(Equation S.1)}$$

$$\mathrm{Re} = \frac{\rho_l \times \Phi \times d_p \times v_l}{\varepsilon \times \mu_l} \quad \text{(Equation S.2)}$$

$$\mathrm{Sc} = \frac{\mu_l}{\rho_l \times D_l} \quad \text{(Equation S.3)}$$

Constraints: $\mathrm{Re} \times \mathrm{Sc} > 500$; $0.6 \leq \mathrm{Sc} \leq 10^4$; $1 \leq \mathrm{Re} < 100$; $0.26 < \varepsilon < 0.935$

where $k_f \equiv$ the film mass transport coefficient (calculated $k_f \approx 4.36 \times 10^{-3}$ m s^{-1} for arsenate and $k_f \approx 5.23 \times 10^{-3}$ m s^{-1} for nitrate); Re is the Reynolds number (unitless); Sc is the Schmidt number (unitless); d_p is the adsorbent particle diameter ($d_p = 0.700 \times 10^{-3}$ m); D_l is the free liquid diffusivity for arsenate or nitrate ($D_{l\text{-}As} = 9.05 \times 10^{-10}$ m^2 s^{-1}; $D_{l\text{-}NO3} = 1.90 \times 10^{-9}$ m^2 s^{-1}) [38, 39]; ε is the bed void fraction ($\varepsilon = 0.634$); μ_l is the dynamic viscosity of water at 20 °C (1.002×10^{-3} N s m^{-2}); ρ_l is the density of water at 20 °C ($\rho_l = 998.2$ kg m^{-3}); Φ is the sphericity of the particle ($\Phi = 1$); and v_l is the liquid superficial velocity ($v_l \approx 0.00208$ m s^{-1}).

Considering that the material was very porous (the particle porosity $\varepsilon_P \approx 0.75$), the impact of surface diffusion was assumed to be negligible. As suggested by Sontheimer et al. [38], the pore diffusion coefficient was estimated using Equation S.4:

$$D_P = \frac{\varepsilon_P \times D_l}{\tau} \quad \text{(Equation S.4)}$$

The tortuosity was estimated using the correlation suggested by Mackie and Meares (Equation S.5) for electrolyte solutions [40]:

$$\tau = \frac{(2-\varepsilon_P)^2}{\varepsilon_P} \qquad \text{(Equation S.5)}$$

where τ is the toruosity factor and ε_P is the particle porosity ($\varepsilon_P \approx 0.75$). The estimated tortuosity value was $\tau \approx 2.1$. The estimated value for the pore diffusion coefficients were $D_{P\text{-}As} \approx 3.5 \times 10^{-6}$ cm^2 s^{-1} for arsenate and $D_{P\text{-}NO3} \approx 6.85 \times 10^{-6}$ cm^2 s^{-1}.

The model breakthrough predictions were compared with the experimental data. Correlations between the model predictions and experimental data characterized by $R^2 > 0.9$ were considered to be sufficient for hypothesis validation.

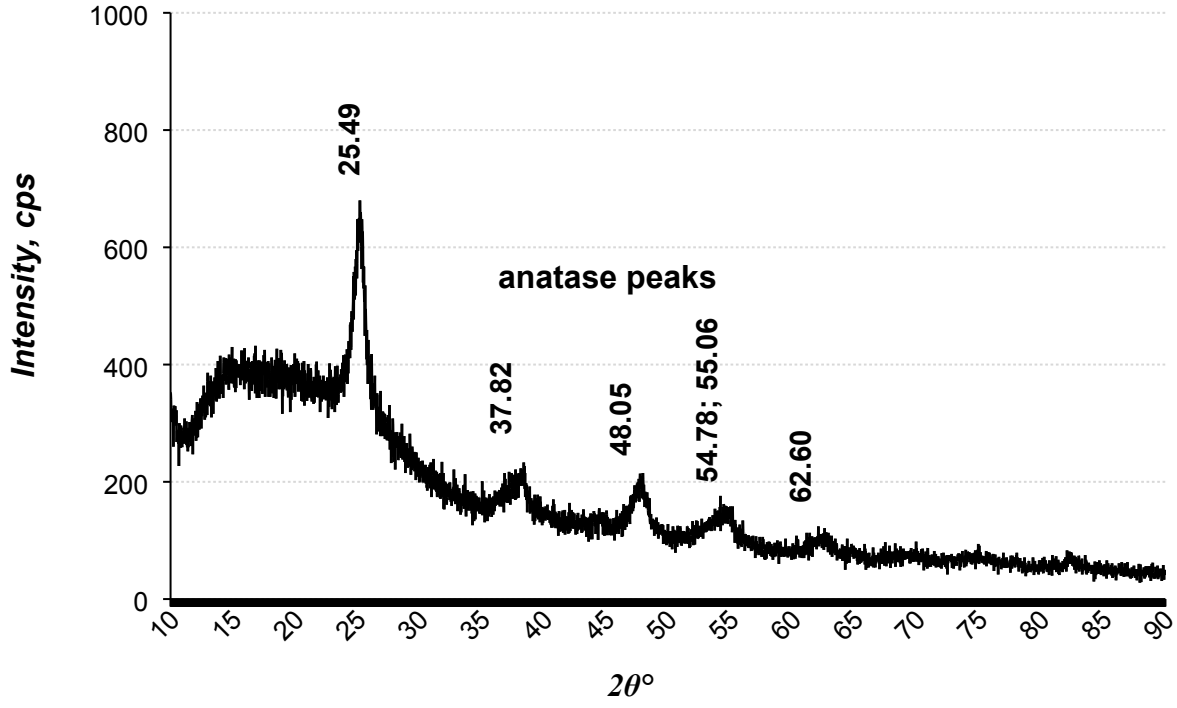

Figure S1. X-ray diffraction peaks indicate existence of anatase crystalline structure of the synthesized titanium dioxide nanoparticles within t e hybrid ion-exchange media.

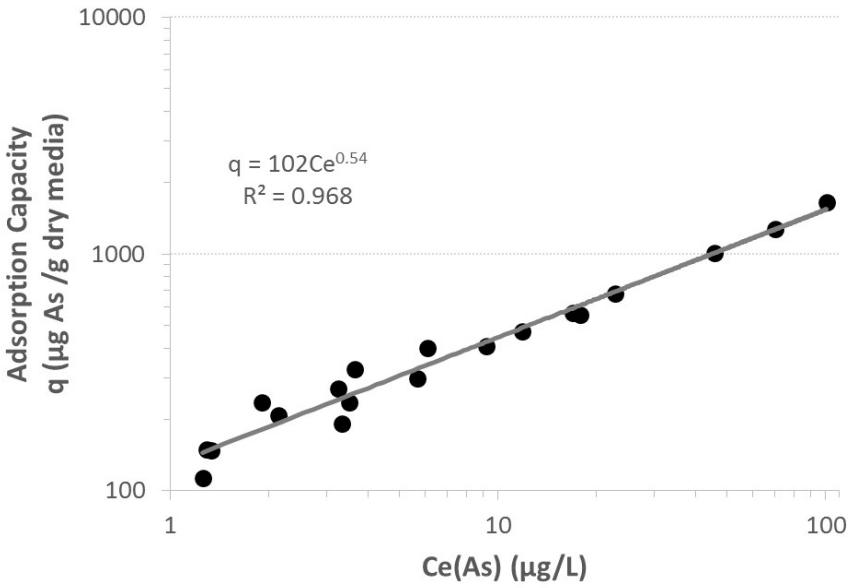

Figure S2. Arsenic sorption isotherms for the Ti-HIX media in 5 mM $NaHCHO_3$ buffered ultrapure water at final pH = 7.2 ± 0.3 and contact time of 3 days ;($C_0 \approx 108$ µg L^{-1} As)

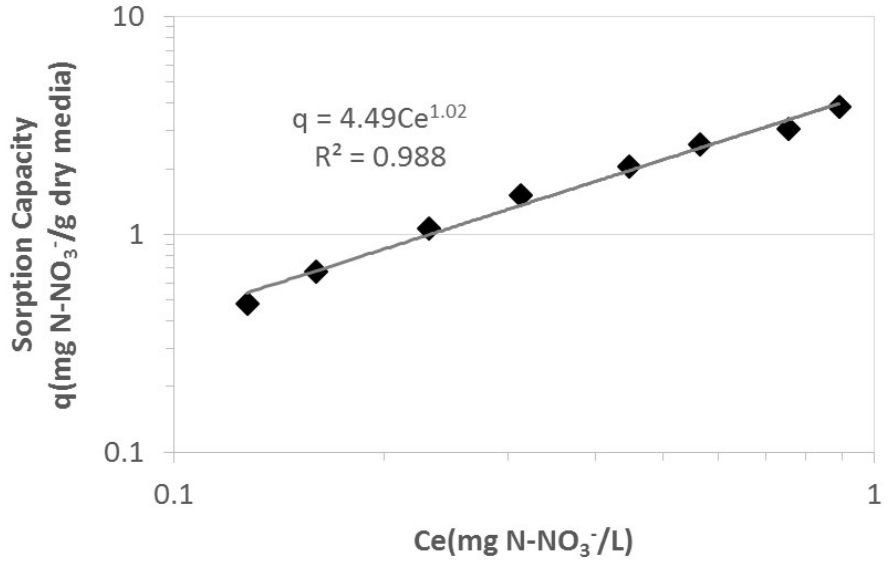

Figure S3. Nitrate sorption isotherms for the Ti-HIX media in 5 mM $NaHCHO_3$ buffered ultrapure water at final pH = 7.2 ± 0.3 and contact time of 3 days; ($C_0 \approx 1.1$ mg L^{-1} $N\text{-}NO_3^-$).

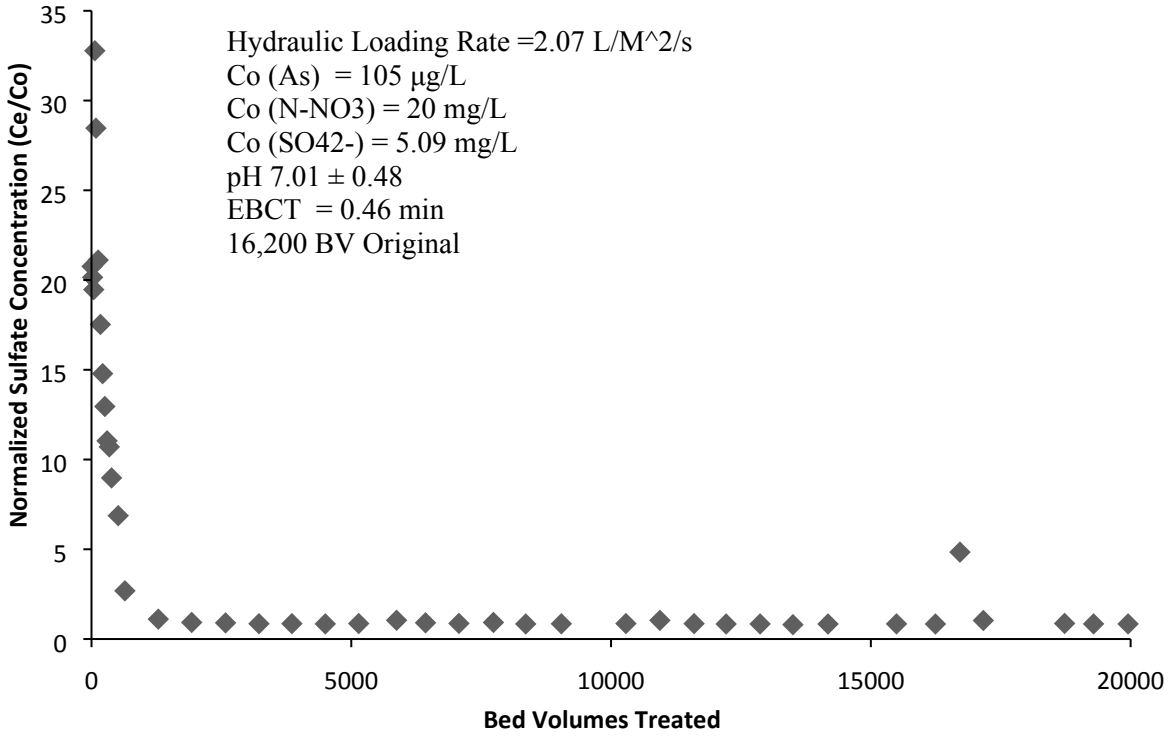

Figure S4. Sulfate breakthrough curves for titanium dioxide nanomaterial-enhanced hybrid ion exchange media under continuous flow regime.