Supporting Information:

Electro-enhanced membrane sorption: A new approach for selective ion separation and its application to phosphate and arsenic removal

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Figure S1. Pictorial representation of electro-assisted selective adsorption of arsenate and phosphate (from simulated groundwater) in the membrane (FeOm). The electrodes are inert and used only to create an electric field in the electrolyte solution and across the FeOm.



4. The 2nd and the 3rd factor influence the local pH near the FeO sorption site in the membrane to release phosphate / arsenate into the solutions

Figure S2. Pictorial representation of electro-assisted desorption of arsenate and phosphate from the membrane (FeOm). The electrodes are inert and used only create an electric field in the electrolyte solution and across the FeOm.



Figure S3. The XRD pattern of the synthesised nanocomposite membrane (FeOm). The filler particles are mostly in the form of iron oxide hydroxide FeO(OH) and a minor fraction in the form of magnetite (Fe₃O₄)



Figure S4. The time dependent current densities through the FeOm in electro-assisted adsorption of phosphate at different applied voltages. The measured current was normalised per unit area (7 cm²) of FeOm. Feed – 25 mg·L⁻¹ phosphate solution. Receiver – deionized water spiked with H_2SO_4 (10⁻⁴ M). Experimental set up is as per Figure 1.

Table S1: Anionic compositions of simulated groundwater before and after adsorption in FeOm, with/without the application of an external electric field.

Species	Solution ion concentration before adsorption (mg·L ⁻¹)	Solution ion concentration after adsorption $(mg \cdot L^{-1})$		
		Adsorption at 0 V ^a -	Electro-assisted adsorption at 10 V ^b	
			Cathode feed	Anode receiver
HCO ₃ ⁻	500.00	487.50	_	_
SO_4^{2-}	9.68	9.55	7.7	1.4
Phosphate	2.00	1.53	1.4	BDL
NO_3^-	15.19	15.05	11.4	3.7
Cl-	353.43	346.12	229	102
Arsenate	18.51 ^{\$}	14.80	13.4	BDL

The active surface area of FeOm was 7 cm² and the volume of the treated solution was 40 mL. Experimental set up of the electro-assisted adsorption experiment (at 10 V) is as per Figure 1. The errors on all the data, as obtained from the analytical methods (ion-chromatography and ICP-AES) were within \pm 5%.

BDL-below detection limit of ICP-AES, after 24 h, bafter 1 h

^{\$}Here, a high concentration of arsenate (compared to typically contaminated groundwater) was used to minimize the error in its analysis by the ICP-AES method.

For the experiment at 0 V, the adsorbed amount in FeOm = solution volume \times {solution ion concentration before adsorption – solution ion concentration after adsorption}.

For the experiment at 10 V, the adsorbed amount in FeOm = solution volume \times {solution ion concentration before adsorption – (conc. in cathodic feed + conc. in anodic receiver)}.

Specific energy consumption (SEC) for phosphate removal by this electro-assisted method

SEC (in kWh·mole⁻¹) for phosphate removal by the proposed electro-assisted sorption method = SEC for electro-assisted adsorption + SEC for electro-assisted desorption.

Now, the SEC for the individual adsorption / desorption can be calculated as follows

$$SEC = \frac{V_{mem} \times I \times t}{1000 \times moles of phosphate sorbed}$$
(S1)

I – current in amperes, t - time in h, V_{mem} – voltage drop across FeOm in volts,

As described in experimental section, the external potential was applied across the membrane by using Pt electrodes positioned \sim 1.5 cm from the FeOm surface on both sides (i.e., in each compartment). The potential drop across the FeOm was obtained from the measured cell currents in presence or absence of the membrane (solution compositions remaining same). Here, we considered the membrane and the solution to be equivalent to resistors in series combination.

The following experimental factors were considered for this calculation

- <u>Electro-assisted adsorption of phosphate into FeOm</u> -feed was 40 mL 25 mg·L⁻¹ phosphate solution, receiver was 40 mL deionized water spiked with H₂SO₄ (10⁻⁴ M), applied voltage at the Pt electrodes was 5 V and the experimental set up was as per Figure 1 (consider only the electro-assisted adsorption schematic i.e. step 1). The corresponding current densities and the phosphate adsorption profiles are shown in Figure S4 and Figure 4a respectively.
- <u>Electro-assisted desorption of phosphate from FeOm</u> 40 mL 1mM KOH in anodic as well as cathodic compartment, applied voltage at the Pt electrodes was 5 V and the experimental set up was as per Figure 7a, i.e, the cathodic and the anodic solutions were mixed and recirculated to maintain the pH. The corresponding phosphate desorption profiles are shown in Figure 7b.

The obtained SEC for electro-assisted adsorption of phosphate into $FeOm = 0.28 \text{ kWh} \cdot \text{mole}^{-1}$ The obtained SEC for electro-assisted desorption of phosphate from $FeOm = 2.6 \text{ kWh} \cdot \text{mole}^{-1}$

Hence, the total energy requirement for phosphate removal by the proposed method = 2.88 kWh·mole⁻¹. It is stressed that the energy consumption is high due to the large distance between the electrodes to the membrane (1 cm), which increase the electric resistance. This number can be decreased dramatically by utilizing membrane stacks with narrow flow channels, as in electrodialysis applications.