Supporting information
Desalinating real shale gas wastewater by membrane distillation: Performance and potentials

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Method S1. MD process cost estimation.

The water production cost (WPC) is the sum of annual fixed charges (AFC) and annual operating cost (AOC). All the parameters necessary for this cost estimation are listed in Tables SM1 and SM2[41,44].

$$\mathrm{WPC} = \frac{\mathrm{AFC} + \mathrm{AOC}}{\mathrm{f} \cdot \mathrm{M} \cdot 365} \tag{SM1}$$

where f and M represent plant availability and capacity, respectively. The AFC consists of direct capital cost (DCC) and indirect capital cost (ICC), with the latter approximating 10% of the former[44]:

$$\mathrm{AFC} = \mathrm{DCC} + \mathrm{ICC} = (1 + 10\%) \cdot \mathrm{DCC} \tag{SM2}$$

DCC involves mainly the cost of the MD process equipment, namely, membrane, pumps, heat exchangers, with the remaining cost as for civil work including installation, building, controlling and so on, assumed to be 1/3 of the former, and the land cost not considered[41,44].

$$\mathrm{DCC} = (1 + 33\%) \cdot (\Psi_{\mathrm{memb}} + \Psi_{\mathrm{pump}} + \Psi_{\mathrm{HX}}) \tag{SM3}$$

$$\Psi_{\mathrm{memb}} = \mathrm{A}_{\mathrm{memb}} \cdot \Pi_{\mathrm{memb}} = \frac{1000 \cdot \mathrm{M}}{24 \cdot \mathrm{J}} \cdot \Pi_{\mathrm{memb}} \tag{SM4}$$

$$\Psi_{\mathrm{pump}} = 4.78\mathrm{E}-06 \cdot \frac{\mathrm{M}}{\mathrm{R}} \cdot \Delta\mathrm{P} \tag{SM5}$$

$$\Psi_{\mathrm{HX}} = \mathrm{A}_{\mathrm{HX}} \cdot \Pi_{\mathrm{HX}} = \frac{\mathrm{Q}_{\mathrm{HX}} \cdot \Delta\mathrm{T}}{\mathrm{U}} \cdot \Pi_{\mathrm{HX}} \tag{SM6}$$

where Ψ is the cost, A is total membrane area required, Π is the specific cost, R is water recovery rate, J is membrane flux, Q is heat to be provided by the heat exchanger and U is global heat transfer coefficient of membrane module. The annual operating costs (AOC) involves membrane replacement, electricity and steam, manpower, brine disposal, consumables, amortization, etc.

$$\mathrm{AOC} = \Psi_{\mathrm{memb,replace}} + \Psi_{\mathrm{electricity}} + \Psi_{\mathrm{steam}} + \Psi_{\mathrm{manpower}} + \Psi_{\mathrm{brine}} + \tag{SM7}$$

$$\Psi_{\mathrm{consumables}} = 15\% \cdot \Psi_{\mathrm{membr}} + \Pi_{\mathrm{electricity}} \cdot \Psi_{\mathrm{electricity}} + \Pi_{\mathrm{steam}} \cdot$$

$$\Psi_{\mathrm{steam}} + \Pi_{\mathrm{manpower}} \cdot \mathrm{f} \cdot \mathrm{M} \cdot 365 + \Pi_{\mathrm{brine}} \cdot \mathrm{f} \cdot \mathrm{M} \cdot 365 + \Pi_{\mathrm{consumables}} \cdot$$

$$\mathrm{f} \cdot \mathrm{M} \cdot 365 + \mathrm{a} \cdot \mathrm{AFC}$$

where a is the amortization factor and

$$\Psi_{\mathrm{electricity}} = \frac{365\mathrm{M} \cdot \Delta\mathrm{P}}{\mathrm{R} \cdot \eta_{\mathrm{pump}}} \cdot 2 \tag{SM8}$$

$$\Psi_{\mathrm{steam}} = \frac{365 \cdot 1000\mathrm{M} \cdot \mathrm{C}_{\mathrm{p,water}} \cdot \Delta\mathrm{T}}{\mathrm{R} \cdot \mathrm{h}_{\mathrm{steam}}} \tag{SM9}$$

where η, R, h and C_p stand for pump efficiency, water recovery, steam specific enthalpy and water specific heat, respectively.

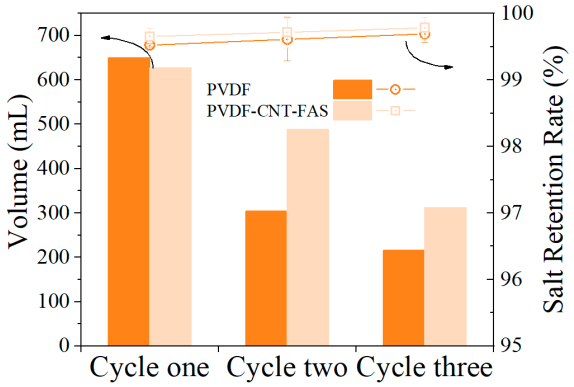

Figure S1. Water recovery volume and salt retention rate on the permeate side after concentration during the three cycles in MD.

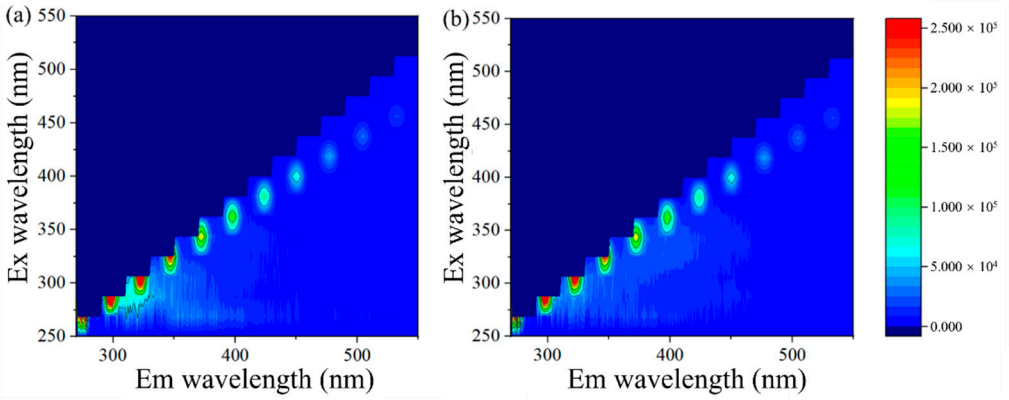

Figure S2. Cleaning of organic foulants on membrane surface with acid: (a) PVDF membrane (b) PVDF-CNT-FAS membrane.

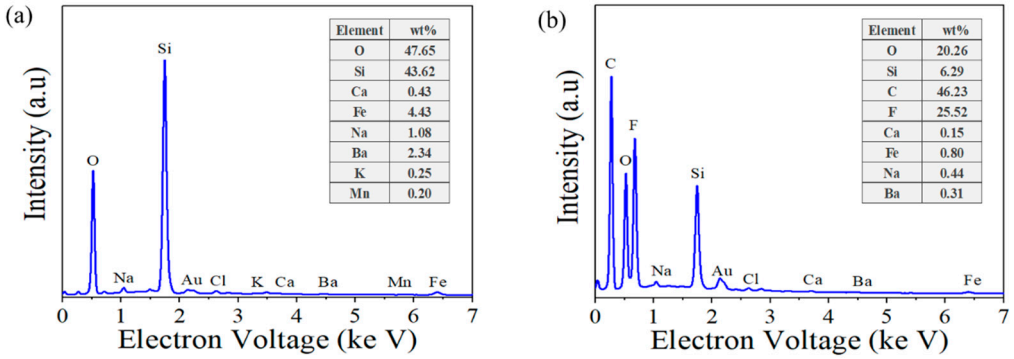

Figure S3. SEM-EDS coupled determination of fouled membrane (a) PVDF and (b) PVDF-CNT-FAS surface elements.

Table S1 Assumption parameters and specific costs in economic analysis.

Pre-define parameters	
Plant availability (f)	90%
Plant capacity, M (m^3/d)	2000
Plant life (year)	20

Interest rate	0.05
Amortization factor (a)	0.08
Operating conditions	
DCMD Feed inlet temperature (°C)	40
DCMD Δt (°C)	25
DCMD flux (kg/m^{2}h)	13.75
DCMD recovery	0.5
DCMD feed pressure (Pa)	120,000
Specific costs	
Electricity cost ($/kwh)	0.08
Membrane cost ($/m^2)	51.76
Membrane replacement (yr^{-1})	0.2
Spares cost ($/m^3)	0.033
Labor cost ($/m^3)	0.03
Chemical cost ($/m^3)	0.018
Brine disposal ($/m^3)	0.0015
Pre-treatment ($/m^2)	0.01
Steam heat exchanger cost ($/m^2)	2000
Heat recovery exchanger cost ($/m^2)	1540

Table S2 Fixed and Operating cost per cubic meter of shale gas wastewater treatment.

Fixed cost		***AFC ($/m^3)***	***Ratio (%)***
Direct investment	Membrane	0.47	56.30
	Pump	0.0032	0.39
	Heat exchanger	0.10	11.66
	Construction	0.19	22.56
Indirect investment	Spares	0.07	9.09
Sum		0.83	100.00
Operating cost		***AOC ($/m^3)***	***Ratio (%)***
Membrane replacement		0.12	8.60
Electric		0.10	7.04
Heat		1.06	77.53
Chemical		0.02	1.22
Maintenance		0.03	2.24
Labor		0.03	2.04
Brine disposal		0.0014	0.10
Pre-treatment		0.02	1.22
Sum		1.36	100.00