Supporting information

An acid stable positively charged polysulfonamide nanofiltration membranes prepared by interfacial polymerization of polyallylamine and 1, 3-benzenedisulfonyl chloride for water treatment

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1 The separation performance data of all membranes (along with statistical variance and average)

Where R, F, S^2, and A represent the rejection (%), the permeation flux (L/m^2 h), the statistical variance, and average, respectively.

Table 1 Effect of the pH value of PAH aqueous solution on the separation performance of the PSA composite membrane evaluated with 1 g/L NaCl solution.

pH	Sample (R)						Sample (F)					
	1	2	3	4	S^2	A	1	2	3	4	S^2	A
8.5	18.45	18.32	17.17	17.30	0.45	17.81	60.97	61.54	62.67	62.10	0.53	61.82
9	32.71	32.11	33.75	33.15	0.48	32.93	49.10	49.71	48.13	48.78	0.43	48.94
9.33	55.19	56.69	55.98	55.9	0.38	55.94	34.73	32.91	33.54	34.1	0.60	33.82
9.5	47.79	49.37	48.60	48.40	0.42	48.58	36.48	34.98	34.84	35.42	0.55	35.13
9.7	41.49	43.15	42.83	41.81	0.63	42.32	40.49	38.73	39.12	40.11	0.68	39.61

Table 2 Effect of the PAH aqueous solution soaking time on the separation performance of the PSA composite membrane evaluated with 1 g/L NaCl solution.

Time(min)	Sample (R)						Sample (F)					
	1	2	3	4	S^2	A	1	2	3	4	S^2	A
5	31.39	32.87	32.16	32.10	0.37	32.13	53.98	52.3	52.98	53.3	0.49	53.14
10	43.92	42.56	42.98	43.6	0.37	43.24	42.34	44.18	43.70	42.72	0.54	43.21
15	49.98	51.48	50.23	51.23	0.54	50.73	39.06	37.2	38.37	37.89	0.62	38.13
25	56.09	57.55	56.93	56.71	0.36	56.82	35.09	33.33	34.08	34.34	0.52	34.21
60	55.19	56.69	55.98	55.9	0.38	55.94	34.73	32.91	33.54	34.1	0.60	33.82

Table 3 Effect of reaction time on the separation performance of the PSA composite membrane evaluated with 1 g/L NaCl aqueous solution.

Time(min)	Sample (R)						Sample (F)					
	1	2	3	4	S^2	A	1	2	3	4	S^2	A
5	27.34	26.9	28.38	27.94	0.43	27.64	56.5	57.09	55.35	55.94	0.56	56.22
15	47.91	49.55	48.26	49.2	0.60	48.73	42.08	43.8	43.08	42.8	0.50	42.94
20	56.09	57.55	56.93	56.71	0.36	56.82	35.09	33.33	34.08	34.34	0.53	34.21
30	55.32	56.92	55.8	56.44	0.50	56.12	31.77	30.03	31.21	30.59	0.57	30.9

Table 4 Effect of PAH and BDSC concentrations on the separation performance of the PSA composite membrane evaluated with 1 g/L MgCl$_2$ solution.

Membrane	Sample (R)						Sample (F)					
	1	2	3	4	S^2	A	1	2	3	4	S^2	A
NF1	65.11	66.39	66.22	65.28	0.42	65.75	52.67	50.83	51.19	52.31	0.77	51.75
NF2	70.77	69.25	70.31	69.71	0.45	70.01	44.36	46.26	44.96	45.66	0.68	45.31
NF3	73.22	71.76	72.12	72.86	0.45	72.49	41.31	43.09	42.64	41.76	0.66	42.2
NF4	53.65	52.51	53.19	52.97	0.22	53.08	55.75	57.47	56.26	56.96	0.57	56.61
NF5	81.12	79.8	80.78	80.14	0.36	80.46	38.5	40.38	39.02	39.86	0.71	39.44
NF6	91.61	93.27	92.78	92.1	0.54	92.44	35.03	33.21	33.98	34.26	0.57	34.10
NF7	91.8	90.61	91.63	90.77	0.36	91.20	30.41	32.19	30.73	31.87	0.74	31.30

Table 5 Rejection and permeation flux of the NF6 membrane for different salts evaluated.

Salt type (1g/L)	Sample (R)						Sample (F)					
	1	2	3	4	S^2	A	1	2	3	4	S^2	A
MgCl$_2$	91.61	93.27	92.78	92.1	0.54	92.44	35.03	33.21	33.98	34.26	0.57	34.10
MgSO$_4$	89.84	88.73	89.23	88.12	0.53	88.98	33.79	35.11	34.35	35.67	0.68	34.73
NaCl	56.09	57.55	56.93	56.71	0.36	56.82	35.09	33.33	34.08	34.34	0.53	34.21
Na$_2$SO$_4$	54.31	55.91	55.16	55.06	0.43	55.11	36.1	34.34	35.18	35.26	0.52	35.22

Table 6 Effect of MgCl$_2$ solution feed concentration on the NF6 membrane performance.

MgCl$_2$(g/L)	Sample (R)						Sample (F)					
	1	2	3	4	S^2	A	1	2	3	4	S^2	A
0.1	93.05	92.30	90.63	91.38	1.11	91.84	38.52	38.91	39.92	39.53	0.39	39.22
0.5	91.03	93.05	92.78	91.30	1.04	92.04	36.1	35.17	35.31	35.95	0.21	35.63
1	91.61	93.27	92.78	92.1	0.54	92.44	35.03	33.21	33.98	34.26	0.57	34.12
1.5	91.56	92.21	92.09	91.71	0.09	91.9	33.96	33.28	33.4	33.84	0.11	33.62
2	90.96	89.68	90.67	89.97	0.35	90.32	32.42	33.54	32.65	33.31	0.28	32.98
3	89.6	88.48	89.42	88.66	0.31	89.04	30.91	33.31	31.25	32.97	1.45	32.11

Table 7 Effect of MgCl$_2$ solution feed pH on separation performance for the NF6 membrane.

pH	Sample (R)						Sample (F)					
	1	2	3	4	S^2	A	1	2	3	4	S^2	A
3	93.89	94.35	94.23	94.01	0.04	94.12	33.72	32.5	32.66	33.56	0.38	33.11
4	94.14	93.64	94.07	93.71	0.06	93.89	33.03	34.19	33.28	33.94	0.30	33.61

		Sample (R)					Sample (F)				
5	92.47	93.61	93.36	92.72	0.28	93.04	34.47	33.19	33.4	34.36	0.43	33.83
6.5	91.61	93.27	92.78	92.1	0.54	92.44	35.03	33.21	33.98	34.26	0.57	34.12
8	92.33	90.87	92.14	91.06	0.55	91.6	33.52	34.68	33.68	34.52	0.34	34.1
9	79.47	78.27	79.18	78.56	0.30	78.87	33.34	34.6	33.76	34.18	0.29	33.97
11	64.94	63.5	64.53	63.91	0.41	64.22	34.83	35.69	35	35.52	0.17	35.26

Table 8 Separation performance of the NF6 membrane for heavy metal salts

Salt type	Sample (R)						Sample (F)					
(1g/L)	1	2	3	4	S^2	A	1	2	3	4	S^2	A
$ZnCl_2$	94.54	95.92	95.42	95.04	0.34	95.23	34.34	33.06	33.33	34.07	0.36	33.70
$CuCl_2$	93.75	92.66	94.18	93.09	0.46	93.42	33.52	34.77	33.03	34.38	0.63	33.90
$CdCl_2$	90.64	91.76	90.98	91.42	0.24	91.20	34.71	33.55	34.58	33.68	0.36	34.13
$Pb(NO_3)_2$	91.47	92.78	92.26	91.96	0.30	92.11	35.12	33.6	33.94	34.78	0.50	34.36

Table 9 The separation performance of the NF6 membrane after expose to 20% (w/v) H_2SO_4 solutions for a fixed period was evaluated with 1 g/L $MgCl_2$ solution.

Time(day)	Sample (R)						Sample (F)					
	1	2	3	4	S^2	A	1	2	3	4	S^2	A
0	91.61	93.27	92.78	92.1	0.54	92.44	35.03	33.21	33.98	34.26	0.57	34.12
3	93.72	91.88	93.25	92.35	0.70	92.8	34.47	36.37	34.66	36.18	0.99	35.42
8	92.46	90.76	92.14	91.08	0.67	91.61	35.52	37.18	35.72	36.98	0.72	36.35
13	90.86	88.98	90.33	89.51	0.70	89.92	36.45	38.37	36.88	37.94	0.80	37.41
18	89.64	88.16	89.21	88.59	0.43	88.9	36.8	38.84	37.45	38.19	0.78	37.82
21	89.44	87.78	88.09	89.13	0.64	88.61	37.5	39.36	39.14	37.72	0.91	38.43
26	87.77	89.67	88.33	89.11	0.70	88.72	39.47	37.73	39.21	38	0.75	38.6
30	89.2	87.44	88.96	87.68	0.79	88.32	37.92	39.5	38.22	39.2	0.58	38.71

Table 10 The PEG rejection curve for the NF6 membrane tested.

PEG(Mw)	Sample (R)					
	1	2	3	4	S^2	A
200	79.23	77.99	78.92	78.3	0.32	78.61
400	86.05	84.61	85.96	84.7	0.61	85.33
800	92.78	91.7	92.13	92.35	0.20	92.24
2000	98	96.44	97.62	96.82	0.51	97.22
4000	99.78	98.9	99.21	99.47	0.14	99.34
6000	100	100	100	100	-	100
10000	100	100	100	100	-	100

2 The various parameter data (ΔP, P, π, M, i, R and T) of all solutes

$\Delta P = P - \pi = P - (i\Delta MRT)$

$1\text{MPa} = 1\text{bar}$

$$R = \left(1 - \frac{C_p}{C_f}\right) \times 100\%$$

$$\Delta M = \frac{C_f - C_p}{M}$$

Where ΔP, P, π represent the effective trans-membrane pressure, the practical pressure (MPa), the osmotic pressure, respectively. ΔM, i, R and T represent the molar concentration difference of the solute between feed and permeate (mol/L), the Van't Hoff factor for the relevant solute, the common gas constant (0.08314 L bar mol^{-1} K^{-1}), the absolute temperature (K), respectively. R, C_f, C_p and M represent the solute rejection (%), the solute concentrations (g/L) for feed solutions, the solute concentrations (g/L) for permeate and the molar mass of solute, respectively.

Table 11 The various parameter data for different inorganic salts.

Solute (1g/L)	M (g/mol)	ΔP (MPa)	P (MPa)	π (MPa)	ΔM (mol/L)	i	R (L bar mol^{-1} K^{-1})	T (K)
MgCl$_2$	95.31	0.4279	0.5	0.0721	0.009694	3	0.08314	298.15
MgSO$_4$	120.36	0.4634	0.5	0.0366	0.007386	2	0.08314	298.15
NaCl	58.44	0.4518	0.5	0.0482	0.009719	2	0.08314	298.15
Na$_2$SO$_4$	142.04	0.4711	0.5	0.0289	0.003886	3	0.08314	298.15
ZnCl$_2$	136.30	0.4481	0.5	0.0519	0.006985	3	0.08314	298.15
CuCl$_2$	134.45	0.4483	0.5	0.0517	0.006947	3	0.08314	298.15
CdCl$_2$	183.32	0.4630	0.5	0.037	0.004975	3	0.08314	298.15
Pb(NO$_3$)$_2$	331.23	0.4793	0.5	0.0207	0.002781	3	0.08314	298.15

Table 12 The various parameter data for MgCl$_2$ with different concentrations.

MgCl$_2$ (g/L)	M (g/mol)	ΔP (MPa)	P (MPa)	π (MPa)	ΔM (mol/L)	i	R (L bar mol^{-1} K^{-1})	T (K)
0.1	95.31	0.4928	0.5	0.0072	0.000963	3	0.08314	298.15
0.5	95.31	0.4641	0.5	0.0359	0.004828	3	0.08314	298.15
1	95.31	0.4279	0.5	0.0721	0.009694	3	0.08314	298.15
1.5	95.31	0.3924	0.5	0.1076	0.014463	3	0.08314	298.15
2	95.31	0.3591	0.5	0.1409	0.018949	3	0.08314	298.15
3	95.31	0.2917	0.5	0.2083	0.028014	3	0.08314	298.15

Table 13 The various parameter data for PEG with different molecular weights.

PEG (g/L)	Mw (g/mol)	ΔP (MPa)	P (MPa)	π (MPa)	ΔM (mol/L)	i	R (L bar mol^{-1} K^{-1})	T (K)
0.05	200	0.49951	0.5	0.00049	0.000197	1	0.08314	298.15
0.05	400	0.49973	0.5	0.00027	0.000107	1	0.08314	298.15
0.05	800	0.49986	0.5	0.00014	0.000058	1	0.08314	298.15
0.05	2000	0.49994	0.5	0.00006	0.000024	1	0.08314	298.15
0.05	4000	0.49997	0.5	0.00003	0.000012	1	0.08314	298.15
0.05	6000	0.49998	0.5	0.00002	0.000008	1	0.08314	298.15
0.05	10000	0.49999	0.5	0.00001	0.000005	1	0.08314	298.15