**Comparative study of PS and PES and their sulfonated forms in antifouling behavior and rejection efficiency**

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**S1: Materials**

Polyethersulfone (Mw of 58000 g/mol) were purchased from Goodfellow, USA. Poly vinyl pyrrolidone (PVP), sodium hydroxide (≥98%), N- methyl -2- pyrrolidinone (99%, NMP), alginic acid sodium salt (≥99.5%, SA), hydrochloric acid (≥37%), N,N-dimethylformamide (≥99.5%), , humic acid (HA, 226.14 g/mol), methanol (99.9%), ethanol ((≥99.8%), and bovine Serum Albumin (≥98%, BSA) were supplied from Sigma-Aldrich Co., USA. Di-sodium hydrogen phosphate dihydrate (98%) was delivered from Scharlau, Spain. H2SO4 (96%) were purchased from Fisher Scientific, UK. Deionized water and reagents broth were obtained in-house.

**S2 Fabrication of SPES**

SPES was sulfonated using 96% H2SO4 at 55°C. First, 4 g of PES was added to a round flask containing 50 mL of H2SO4 at ambient temperature with continuous agitation. The flask was then heated to 55°C in a silicon-oil bath. The reaction proceeded overnight at this temperature. Upon completion, the blend was cooled down to the ambient temperature and settled in a large amount of ice with vigorous stirring. The SPES was then isolated, washed with distilled water to remove any excess H2SO4, and dried under vacuum at 30°C overnight.

### **S3 Synthesis of SPS**

SPS was performed using chlorosulfonic acid. A 3-gram sample of dried PS was dissolved in 50 mL of anhydrous 1,2-dichloroethane in a 250 mL three-neck flask equipped with a mechanical stirrer, condenser, and nitrogen purge inlet. The solution was purged with nitrogen for 1 hour. Subsequently, trichloromethylsilane (1.5 mL) and chlorosulfonic acid (2.33 g) were dropped with continuous stirring at 30°C for 12 hours. The SPS was then isolated by adding 20 mL of methanol, evaporating the solution at room temperature, washing the product with deionized water, and drying it.

**S4: Membrane characterizations**

The functional moieties on the fabricated membranes (PES, PS, SPES, and SPS) were analyzed using Fourier-Transform Infrared Spectroscopy (FTIR, IR Tracer-100, Shimadzu, Japan), covering a scan range from 4000 to 400 cm-1. Thermal gravimetric analysis (TGA) was conducted in an air atmosphere using the STA-449F3 (Shimadzu, Japan), heating at a rate of 10°C per minute from 50 to 600°C to assess the thermal durability of the membranes. The topography, cross-section, and morphology of the membranes were characterized using Field Emission Scanning Electron Microscopy (FESEM, Thermo Scientific, Quattro ESEM, Thermo Fisher, Waltham, MA, USA). Hydrophilicity was evaluated by measuring contact angles with a Data Physics SCA20 Goniometer equipped with a digital camera. Tensile properties were analyzed using a Shimadzu EZ-S tensile tester. The porosity of the membrane was evaluated utilizing Equation (1) [9-11]:

$$ε=\frac{W\_{1}- W\_{2}}{A×t×ρ} (1)$$

Where ρ is the density, A is the membrane's area, and t is the thickness. W1and W2​ the membrane’s wet and dry mass, respectively. Water uptake (ϕ) was assessed using the formula (2) [30]:

$φ \left(\%\right)=\frac{W\_{w}-W\_{d}}{W\_{d}}$ $×$ 100 (2)

Where Ww, and Wd are the membrane’s wet and dry weight (Kg).

To ensure consistent water flux, all membranes were pre-pressurized with water and maintained at 1 bar for 30 minutes. The water flux (Jw​) was assessed using the formula (3). [30, 31]:

$$J\_{w}=\frac{m}{ρ×A×t} (3)$$

where t is the permeation’s time, ρ is the density, A is the area of the membrane and m is the mass of the permeate.

**S5: The membrane’s antifouling performance**

The membrane’s antifouling performance was explored with nature organic matter (NOM) foulant. NOM foulant UF assessment were conducted at ambient conditions (1 bar, pH 7, 100 ppm NOM (800 mL). The rejection was assessed as per Equation (1):

$$R\_{f}\left(\%\right)=\frac{(C\_{feed}^{0}-C\_{permeate}^{t})}{C\_{feed}^{o}} x100 (1)$$

Here, *Cf​*, and *Cp* are the NOM concentration in the feed and permeate solution.

The water flow recovery ratio (FRR) was used to evaluate UF membrane antifouling efficacy. Initially, the pure water flow (Jw1​) of membranes was determined, then the permeate medium was changed to a 100 ppm NOM aqueous solution. After filtration for 30 minutes, the membrane was disinfected, placed back in the device, and the pure water flow was measured again and recorded as Jw2. The flux recovery ratio (FRR) was calculated using Equation (2):$FRR\left(\%\right)=\frac{Jw\_{2}}{Jw\_{1}}x100 (2)$

Fouling resistance was determined through the assessment of three crucial parameters: the reversible fouling ratio (Rr, %), the irreversible fouling ratio (Rir, %), and the total fouling ratio (Rt, %). These values were computed using Equations (3), (45), and (5), in the respective order:

$$ R\_{r}= \frac{(J\_{w2}-J\_{fx})}{J\_{w1}} x100 (3)$$

$$R\_{t}= \frac{(J\_{w1}-J\_{fx})}{J\_{w1}} x100 (4)$$

$$ R\_{ir}= \frac{(J\_{w1}-J\_{w2})}{J\_{w1}} x100 (5)$$

Here Jw1 (Lm−2 h−1) represents the bare water flux, Jw2 (L m−2 h−1) stands for water flux after washing, and Jfx (L m−2 h−1) is the permeation flux.

The surface free energy (ΔGSL) between the membrane surface and liquid was measured using the estimated contact angle utilizing the Young-Dupre equation (Eq. (6)):

ΔGSL = (1+cosθ)γ (6)

where θ is the contact angle at a fixed time interval, and γ is the surface tension (72.83 mJ/m2).