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Review

Forward osmosis for application in wastewater treatment: A review

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ABSTRACT

Research in the field of Forward Osmosis (FO) membrane technology has grown significantly over the last 10 years, but its application in the scope of wastewater treatment has been slower. Drinking water is becoming an increasingly marginal resource. Substituting drinking water for alternate water sources, specifically for use in industrial processes, may alleviate the global water stress. FO has the potential to sustainably treat wastewater sources and produce high quality water. FO relies on the osmotic pressure difference across the membrane to extract clean water from the feed, however the FO step is still mostly perceived as a "pre-treatment" process. To prompt FO-wastewater feasibility, the focus lies with new membrane developments, draw solutions to enhance wastewater treatment and energy recovery, and operating conditions. Optimisation of these parameters are essential to mitigate fouling, decrease concentration polarisation and increase FO performance; issues all closely related to one another. This review attempts to define the steps still required for FO to reach full-scale potential in wastewater treatment and water reclamation by discussing current novelties, bottlenecks and future perspectives of FO technology in the wastewater sector.

Contents

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Nomenclature

A	water permeability constant, m/s.Pa
AFM	atomic force microscopy, –
AHA	Aldrich Humic Acid, –
AL	active layer, –
B	solute permeability coefficient, m/s
BSA	bovine serum albumin, –
CA	cellulose acetate, –
c_{draw}	concentration of the draw solution, –
CECP	concentrative external concentration polarisation, –
CEOP	cake enhanced osmotic pressure, –
CF	cross-flow, –
c_{feed}	concentration of the feed solution, –
COD	Chemical Oxygen Demand, –
CP	concentration polarisation, –
CS	corrugated spacer, –
CTA	cellulose triacetate, –
D	solute diffusion coefficient, m^2/s
DICP	dilutive internal concentration polarisation, –
DS	draw solution, –
ECP	external concentration polarisation, –
EDX	energy dispersed X-ray, –
EfOM	effluent organic matter, –
EPS	extracellular polymeric substances, –
FO	forward osmosis, –
FS	feed side, –
FTIR	Fourier transform infrared spectroscopy, –
HF	hollow fibre, –
ICP	internal concentration polarisation, –
J_s	salt flux, g/m^2 h
J_w	water flux, l/m^2 h
K_m	mass transfer coefficient, m/s
l	thickness of support layer, mm
MBR	membrane bioreactor, –
MF	microfiltration, –
NF	nanofiltration, –
NOM	natural organic matter, –
NPD	normalised pressure drop
OMBR	osmotic membrane bioreactor, –
PA	polyamide, –
PAI	polyamide–imide, –
PAN	polyacrylonitrile, –
PBI	polybenzimidazole, –
PDA	polydopamine, –
PEG	poly(ethylene glycol), –
PES	polyethersulphone, –
PNF	plate and frame, –
PS	polysulphone, –
PRO	pressure retarded osmosis, –
R	Rejection of solute, %
Rg	universal gas constant, L atm K^{-1} mol^{-1} or J/mol K
RO	reverse osmosis, –
S	membrane structure parameter, mm
SD	Solution-diffusion, –
SEM	scanning electron microscopy, –
SL	support layer, –
SWFO	spiral-wound forward osmosis, –
T	Temperature, K
TDS	total dissolved solids, –
TEP	transparent exo-polymer particles
TFC	thin-film composite, –
TrOC	trace organic contaminant, –
UF	ultrafiltration, –
β	van't Hoff coefficient, –
$\Delta\pi$	osmotic pressure differential ($\pi_{DS} - \pi_{FS}$) bar
ε	porosity of the support layer –
π	osmotic pressure bar
σ	reflection coefficient, –
τ	tortuosity of the support layer, –