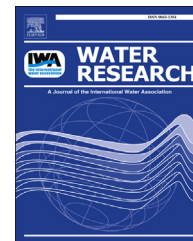




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## Review

# 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.

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

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