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Supporting Information

Interpenetrating polymer networks for desalination and water remediation: A comprehensive review of research trends and prospects

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Table S1: Desalination using IPN architecture

Sl. No	IPN system	Types of IPN	Desalination application and remarks	References
1	Interpenetrating polymer network of Poly(acrylic acid-co-ethyleneglycol dimethacrylate) (XPAA) and ethoxylated polyethyleneimine (EPEI)	Full IPN	NaCl from water by a thermally reversible (Sirotherm) process using 3000 mg L^{-1}	(Chanda et al., 2010)
2	Hydrogels of N-isopropylacrylamide (NIPAm) in the presence of polysodium acrylate (PSA) or polyvinyl alcohol (PVA)	Semi IPNs	Temperature cycle driven FO desalination at 2000 ppm NaCl concentration	(Cai et al., 2013)
3	Hydrophobic/hydrophilic interpenetrating network composite nanofibers (HH-IPN-CNF) using polyethylene terephthalate (PET) as hydrophobic component and polyvinyl alcohol (PVA)	Full IPN	Water flux of 47.2 LMH and low salt leakage (9.5 gMH) at 0.5 M NaCl solution	(Tian et al., 2014)
4	Cation exchange membrane of polystyrene/PVDF	Semi IPN	96% electrodialysis desalination 2000 ppm	(Lei et al., 2014)
5	Microporous PVDF-PDMS membrane	Semi IPN	99.9% NaCl removal at 30 g L^{-1} concentration	(Sun et al., 2017)

6	PDMS/PVDF membranes	Semi IPNs	99.9% NaCl rejection in vacuum membrane distillation	(Qu et al., 2018)
7	Cation exchange membranes using PVC-St/DVB /SGO based IPN CEM	Full IPN	82% NaCl rejection by electrodialysis.	(Rajput et al., 2018)
8	Polyamide (PA) and poly (N-vinyl-2-pyrrolidone) (PVP)	Semi IPNs	Water flux and salt rejection increased 43.2% and 0.2% (2000 ppm NaCl)	(C. Wang et al., 2021)
9	MOF-incorporated Cu-based alginate/PVA hydrogel (MOF-Alg(Cu)/PVA) beads	Full IPN	43% NaCl at 10000 ppm by Ion adsorption desalination technique	(Lee et al., 2021)
10	Crosslinked poly(2-acrylamido-2-methyl-l-propanesulfonic acid-co-acrylamide) (P(AMPS-AM)) and linear polyelectrolyte polyacrylic acid (PAA)	Semi IPNs	Water flux of 2.20 L m^{-2} h^{-1} (LMH) from 2000 ppm NaCl solution	(Xu et al., 2022)

Table S2: Dye removal using IPN architecture

Sl. No.	IPN system	Type of IPN	Dye removal efficiency and remarks	References
1.	IPN gel beads from SA, MAPTAC (3-(methacrylamido) propyl trimethyl ammonium chloride) and/or AM (acrylamide)	Semi IPN	Adsorption of cationic dye Taiacryl Brilliant Red 4GN: 21 mg g-1	(Kusuktham, 2006)
2.	Sodium alginate/acrylamidesemi-interpenetrating polymer networks ((NaAlg/AAm)IPN)	Semi IPN	Adsorption capacity followed the order: Magenta< Safranine-O<Methylene Blue< Methyl Violet	(Şolpan et al., 2008)
3.	Polystyrene/polyamide macroporous crosslinked IPN	Full IPN	Adsorption of quercetin pigment: 8.6 mg mL^{-1}	(Liao et al., 2010)
4.	poly (acrylamide-co-acrylic acid) and polyvinylalcohol hydrogels	Semi IPN	MB: Removal 95%	(Zendehdel et al., 2010)
5.	Cross-Linked Chitosan-Poly(acrylamide) Adsorbent Hydrogels	Full IPN	Adsorption of EY-4GL: 64.5 mg g^{-1} and S-Blue: 38.7 mg g^{-1}	(Ekici et al., 2011)
6.	Hydrogel from polyvinyl alcohol and poly (acrylic acid-co-hydroxyethylmethacrylate) copolymer	Semi IPN and Full IPN	Maximum adsorption capacity for Rhodamine B: 2.9 mg g^{-1}, Methyl violet: 3.7 mg g^{-1}	(Mandal et al., 2012)
7.	Hydrogels of PEG and (AAm/SMA) copolymer of acrylamide/sodium methacrylate	Semi IPN	Janus Green B dye: Removal 90%	(Üzüm & Karadağ, 2012)
8.	Polymethacrylic acid grafted cellulose–bentonite (PMAA-g-	Full IPN	MB: removal 99.9%	(Anirudhan & Tharun, 2012)

	Cell/Bent) IPN			
9.	Hhydrogels from PEG (polyethylene glycol) and Aam (acrylamide)	Semi IPN	Adsorption capacities of acid red 17: 342.54 mg g^{-1}, acid orange 7: 221.1 mg g^{-1} and methyl orange: 185.24 mg g^{-1}	(S. Zhao et al., 2012)
10.	Hydrogels based on polyacrylamide and chitosan	Semi and Full IPN	High anionic dye adsorption capacity of direct blue 1: 2.804 mg g^{-1} by semi IPN and high cationic dye adsorption of MB: 6.744 mg g^{-1} by full IPN	(Dragan et al., 2012)
11.	Carboxymethylcellulose/ poly(acrylamide-co-hydroxyethyl methacrylate) hydrogel	Semi IPN	Maximum adsorption capacity of Methyl violet (MV): 450 mg g^{-1}, Basic Fuchsin: 350 mg g^{-1}	(Bhattacharyya & Ray, 2013)
12.	Poly(acrylamide-aniline)-grafted gum ghatti based crosslinked conducting hydrogel	Semi IPN	MG dye removal 98% after 20 hrs of operation	(K. Sharma et al., 2013)
13.	Full IPN of polymethacrylic acid and chitosan	Full IPN	MV: 91% and CR: 82% removal	(Maity & Ray, 2014)
14.	Poly(ether amine) (hPEA)/Poly(vinyl alcohol) (PVA) hyperbranched Interpenetrating Network (IPN)	Full IPN	Fluorescein dyes: Removal 90%	(P. Zhang et al., 2014)
15.	Semi-interpenetrating polymer network sodium alginate and isopropyl acrylamide	Semi IPN	600 mg g-1 adsorption of RB 4 (Reactive Blue) dye	(Dhanapal & Subramanian, 2014)

16.	IPN hydrogel from acrylic copolymer and chitosan	Full IPN	98% CR and 94% MV dye removal	(Mandal & Ray, 2014)
17.	P(NIPAM-MBAM) hydrogel microspheres (poly(N-isopropylacrylamide) (PNIPAM) and poly(methacrylic acid)	Full IPN	3.7 mg g-1 Magenta and 0.7 mg g-1 CR adsorption	(Ahmad et al., 2014)
18.	Semi IPN hydrogels from GEL (gelatin) and/or PEG (poly (ethylene glycol)) with AAm (acrylamide) and 4-styrenesulfonic acid sodium salt	Semi IPN	93.34% MV dye adsorption percentage	(Kundakci & Karadağ, 2014)
19.	TiO2 nanoparticle immobilized Sodium alginate-polymethacrylic acid hydrogel	Semi IPN	MB: Removal 93%	(Lučić Škorić et al., 2015)
20.	Acrylic acid-2-hydroxyethyl methacrylate IPN hydrogels	Semi and Full IPN	>99% MV and >93% removal of MV and Fuchsine dye	(Bera et al., 2015)
21.	In-situ crosslinked PES (polyethersulfone) and modified chitosan hydrogel adsorbent	Semi IPN	CR dye: Removal 80%	(R. Wang et al., 2015)
22.	Guar gum/acrylic acid hydrogel (Ggum-cl-poly(AA-ipn-aniline)) IPN	Semi IPN	MB: Nearly 94% and demonstrated antibacterial activity	(R. Sharma, Kaith, et al., 2015)
23.	Chitosan/gelatin porous materials	Full IPN	Acid orange II maximum adsorption capacity 573 mg g^{-1}	(Cui et al., 2015)

24.	Ggum-cl-poly(IA) crosslinked hydrogel (itaconic acid and Guaran polysaccharide)	Semi IPN	Removal 84.5% and 81% of MB dye in neutral and acidic pH, respectively	(R. Sharma, Kalia, et al., 2015)
25.	IPN hydrogels based on chitosan (CS) and poly(acrylic acid) (PAA)	Semi IPN	Adsorption capacity of basic BB12 (Nil Blue) dye: 430 mg g^{-1}	(J. Wang & Li, 2015)
26.	Semi IPN hydrogel from chitosan and starch	Semi IPN	Adsorption capacity of DR 80 dye: 312.77 mg g^{-1}	(Ngwabebhoh et al., 2016)
27.	Porous chitosan/hydroxyapatite composite membrane	Sequential IPN	DB (direct black): Removal 98%	(Shi et al., 2017)
28.	Guar gum-g-(acrylic acid-co-acrylamide-co-3-acrylamido propanoic acid) hydrogel	Full IPN	Maximum adsorption of MB: 27.06 mg g^{-1} and SF (safranine F) dye: 39.35 mg g^{-1}, and effective heavy metal removal	(Singha et al., 2017)
29.	Xanthan gum, PVA and tartaric acid-based semi IPN hydrogel	Semi IPN	RB: 70% and AO (auramine-O): 63% removal	(Sukriti et al., 2017)
30.	Aloe vera–acrylic acid-co-acrylamide	Semi IPN	Malachite green (MG): Removal 94%	(Saruchi et al., 2018)
31.	Av-cl-poly(AA-ipn-AAm) (aloe vera, acrylic acid, acrylamide IPN) microwave assisted	Semi IPN	MG: Removal 97.3%	(V. Kumar et al., 2018)
32.	Poly(acrylic acid)/poly(vinyl alcohol)/yeast superabsorbent polymers (PAA/PVA/yeast SAPs)	Semi IPN	Maximum adsorption capacity of 50 mg g^{-1} for MB	(Feng et al., 2018)

33.	Hydrogel from (gum copal alcohols-collagen)-co-poly(acrylamide) and acrylic acid	Full IPN	Adsorption capacity of MB: 1.7 mg g^{-1}	(Kaur & Jindal, 2018)
34.	Hydrogel based on gum copal-collagen (GcA-coll)	Full IPN	MG (Malachite Green) dye: removal 88%	(Kaur et al., 2018)
35.	QPVA (quartarnized PVA)/acrylamide full IPN alkaline membranes	Full IPN	CR removal better than RB in binary dye systems and single system	(J. Wang et al., 2018)
36.	PVA/CNC (cellulose nanocrystal)/polyHEMA hydrogels	Full IPN	MB: 91% and (xylenol orange) XO: 93% removal	(Bai et al., 2018)
37.	Cellulose filament/poly(NIPAM-co-AAc) hybrid hydrogels	Semi IPN	MV dye: Removal 226.02 mg g^{-1}	(M. Zhang et al., 2018)
38.	Gum acacia/sodium alginate hydrogel	Semi IPN	MG dye: removal 95.39%, CV (crystal violet): 94.56% and AO (auramine-O): 97.49%	(A. K. Sharma et al., 2019)
39.	N,N,N-trimethyl chitosan (TMC) and xanthan gum (XG) hydrogel	Full IPN	CV dye: removal 94.4 % with antibacterial activity	(Abu Elella et al., 2019)
40.	Sodium humate/poly(acrylamide-co-methacrylic acid)/kaolin semi-interpenetrating polymer network hybrid hydrogel	Hybrid IPN	Adsorption of MB dye: 833.33 mg g^{-1}	(Yilmaz et al., 2019)
41.	Carboxymethyl cellulose/poly(acrylic acid) interpenetrating polymer network hydrogels	Full IPN	Adsorption of MB dye: 613 mg g^{-1}	(Toledo et al., 2019)

42.	PAA-XG-GO Semi IPN nanocomposite (cross-linked poly acrylic acid/xanthan gum/graphene oxide)	Semi IPN	MB: Removal 88.5% and swelling upto 485%	(Hosseini et al., 2020)
43.	Graphene oxide decorated superporous polyacrylamide hydrogel (MCC/poly (AAm-co-NaAc)/r-GO (L))	Full IPN	MB: 98% and RB: 97.6% removed	(Sarkar et al., 2020)
44.	PVA/KHA/GG Hydrogel (polyvinyl alcohol/potassium humate/guar gum)	Semi IPN	Maximum adsorption capacity for MB dye: 1166.73 mg g^{-1} and Pb(II): 625.21 mg g^{-1}	(Niu et al., 2020)
45.	Cassava starch-graft-poly(acrylamide) hydrogel	Full IPN	>85% of MB removal within less than 10 hrs	(Junlapong et al., 2020)
46.	Copolymer poly(di(ethylene glycol) methyl ether methacrylate-co-poly(ethylene glycol) methyl ether methacrylate) (P(MEO2MA-co-OEGMA300)) in alginate–Ca2+ hydrogel	Hybrid IPN	MB: Removal 96%	(N. Hu et al., 2020)
47.	Poly(vinyl alcohol-g-acrylamide)/SiO_2@ZnO photocatalytic hydrogel composite	Semi IPN	Maximum adsorption capacity for MB: 757 mg g^{-1}	(Maijan et al., 2020)
48.	Starch-grafted poly(N,N-dimethyl acrylamide) hydrogel	Full IPN	Acid Red 8: removal 91%	(Sadik et al., 2020)
49.	Self-supported gel filter membrane with Ca^{2+} alginate network and covalently crosslinked	Full IPN	MB: removal 93% and DR: removal 95%	(J. Hu et al., 2020)

	polyacrylamide network			
50.	Polyvinyl Alcohol−Alginate/Bentonite Semi-Interpenetrating Polymer Network Nanocomposite Hydrogel Beads	Semi IPN	Maximum adsorption capacity of MB: 51.34 mg g^{-1}	(Aljar et al., 2021)
51.	KG-Gl-PVA Semi IPN Microspheres (katira gum/polyvinyl alcohol)	Semi IPN	96.92% of Bismark brown-yellow dye removal	(A. Kumar et al., 2021)
52.	Solid state liquid crystal shell IPN	IPN via microfluidic method	MB and AR37: Removal 99%	(Gwon & Park, 2021)
53.	Hydroxyl-terminated polybutadiene (HTPB) and multifunctional isocyanate (MFI) membrane	Semi IPN	MB and MO dye removal 98%	(Nozad et al., 2022)
54.	PVDF/PDA IPN membrane	Sequential IPN	>97% removal of MB and CR dyes	(Sen Gupta et al., 2022)
55.	Pullulan/PDA Semi IPN hydrogels (sPDA)	Semi IPN	Maximum adsorption capacity of 107 mg g^{-1} for Crystal violet (CV)	(Wu et al., 2022)
56.	Poly(vinyl alcohol)/partially hydrolyzed polyacrylamide/graphene oxide Semi IPN nanocomposite hydrogel	Semi IPN	Maximum adsorption capacity of 714.8 mg g^{-1} at 30°C for MB dye	(Rahmatpour et al., 2022)
57.	TFC semi IPN membrane from 3, 5-diaminobenzoic acid (DABA) and piperazine (PIP)	Semi IPN	MB: removal 99%	(Waheed et al., 2022)

58.	PVDF-Pd (palladium)/ Semi IPN composite membrane	Semi IPN	CR and DB dyes removal >99%	(Zhai et al., 2022)
59.	Semi-interpenetrating network based on xanthan gum-cl-2-(N-morpholinoethyl methacrylate)/titanium oxide	Semi IPN	Adsorption capacity of MB: 63.34 mg g^{-1} and CV: 83.25 mg g^{-1}	(Taktak & Özyaranlar, 2022)
60.	Semi IPN hydrogels based on acrylamide (AAm) and itaconic acid (ITA)	Semi IPN	Adsorption capacity of MB: 15 mg g^{-1} and MG: 8 mg g^{-1}	(Ciftbudak & Orakdogen, 2022)
61.	Poly(N-isopropylacrylamide-co-methacrylic acid) P(NIPA-MA) gels	Semi IPN	MV(methyl violet): removal 75%	(Kalkan & Orakdogen, 2022)
62.	Chitosan- and Alginate-Based Hydrogels	Semi IPN	MB dye removal 96% within 10 mins	(ALSamman & Sánchez, 2022)
63.	Cellulose acetate/acrylic acid-glutaraldehyde semi-interpenetrating networks	Semi IPN	MB: removal 90%	(Rana et al., 2022)
64.	Methylcellulose/tannic acid complex particles coated on alginate hydrogel scaffold	IPN via Pickering emulsion	MB dye adsorption: 791.17 mg g^{-1}	(Abebe & Kim, 2022)

Table S3: Miscellaneous water remediation application using IPNs based material				
Sl. No	**IPN system**	**Types of IPN**	**Miscellaneous application in water remediation and remarks**	**References**
1	Sodium alginate/acrylamide) based IPN	Semi IPN	Detection of Ni^{2+}, Cd^{2+}, and Pb^{2}	(Şolpan & Torun, 2005)
2	Starch/acryl amide-based hydrogels	Full IPN	adsorption of heavy metal ions like Cu^{2+} and Ni^{2+} adsorption	(Peñaranda A. & Sabino, 2010)
3	Poly(polyethylene glycol diacrylate) poly(PEGDA) and poly(methacrylic acid) (PMAA) IPN hydrogel	Full IPN	Cu(II), Cd(II), or Pb(II) ion solutions	(J. Wang et al., 2011)
4	Polyvinyl alcohol/poly (acrylic acid-co-acrylic amide) (PVA-P(AA-co-AM)) hydrogels	Semi IPN	Cobalt (II) adsorption	(X. Wang et al., 2016)
5	IPN of acrylamide (AAm) and 1,4-butanediol vinyl ether (BVE)	Full IPN	Adsorption and determination of Cu^{2+}, Ni^{2+} and Zn^{2+} ions	(J. Wang et al., 2016)
6	2-hydroxyethyl methacrylate (HEMA), acrylamide (AM), polyvinyl alcohol (PVA) and chitosan (CS)	Full IPN	Excellent antibacterial activity against E. *coli*	(Panpinit et al., 2020)
7	interpenetrating polymeric networks (IPN) based on sodium alginate, carrageenan and bentonite	Full IPN	Excellent adsorption efficiency of methylene blue, Fe^{3+}, Ni^{2+}, and Cr^{3+} ions is 1271, 1550, 1500 and 1540 mg/g adsorbent, respectively.	(Al-Sakkari et al., 2020)
8	Chitosan/polyacrylamide IPN modified with α-ketoglutaric acid	Semi IPN	More than 90% selective adsorption for Cu(II), Pb(II), and Zn(II) in a mixture of heavy metal ions upto five adsorption-desorption cycles	(Z. Zhao et al., 2021)

9	Poly(2-hydroxyethyl methacrylate-co-acrylamide)/poly(vinyl alcohol) (P(HEMA-co-AM)/PVA) IPN hydrogels	Full IPN	Cu(II) and Pb(II) ions adsorption	(Tanan et al., 2021)
10	Chitosan/gelatin-based IPN incorporated with melanin-coated titania hollow nanospheres (CG@MPT-h)	Full IPN	Solar-Driven Wastewater Treatment	(X. Wang et al., 2021)
11	Cellulose Nanofibril/Chitosan IPN hydrogel crosslinked by Fluorescent carbon dots hydrogel	Full IPN	Simultaneously detection and adsorbent of Cu(II) and Cr(VI) in water.	(Chen et al., 2022)
12	Thermo-responsive Semi IPN/PVDF@Pd bilayer composite membrane	Semi IPN	Water flux 27.0 L m^{-2} h^{-1} bar^{-1} and 99.74% adsorption of p-nitrophenol	(S. Wang et al., 2022)

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