



University of Waterloo

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# **Polyvinylamine-enhanced Ultrafiltration for Removal of Heavy Metals from Wastewater**

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# Introduction

## Contamination of heavy metals

**Heavy metals**

hydrogen 1 H 1.0079	helium 2 He 4.0026																
lithium 3 Li 6.941	beryllium 4 Be 9.0122																
sodium 11 Na 22.990	magnesium 12 Mg 24.305																
potassium 19 K 39.098	calcium 20 Ca 40.078																
rubidium 37 Rb 85.468	strontium 38 Sr 87.62																
cesium 55 Cs 132.91	barium 56 Ba 137.33																
francium 87 Fr [223]	radium 88 Ra [226]																
		scandium 21 Sc 44.956	titanium 22 Ti 47.867	vanadium 23 V 50.942	chromium 24 Cr 51.996	manganese 25 Mn 54.938	iron 26 Fe 55.845	cobalt 27 Co 58.933	nickel 28 Ni 58.693	copper 29 Cu 63.546	zinc 30 Zn 65.39	gallium 31 Ga 69.723	germanium 32 Ge 72.61	arsenic 33 As 74.922	selecnium 34 Se 78.96	zinc 35 Br 79.904	krypton 36 Kr 83.80
		yttrium 39 Y 88.906	zirconium 40 Zr 91.224	niobium 41 Nb 92.906	niobium 42 Mo 95.94	technetium 43 Tc [98]	ruthenium 44 Ru 101.07	rhodium 45 Rh 102.91	silver 46 Ag 106.42	cadmium 47 Cd 112.41	indium 49 In 114.82	tin 50 Sn 118.71	antimony 51 Sb 121.76	tellurium 52 Te 127.60	iodine 53 I 126.90	bromine 54 Br 159.808	xenon 55 Xe 131.29
		lanthanum 57 La 138.905	cerium 58 Ce 140.12	praseodymium 59 Pr 140.91	neodymium 60 Nd 144.24	promethium 61 Pm [145]	samarium 62 Sm 150.36	europium 63 Eu 151.96	gadolinium 64 Gd 157.25	terbium 65 Tb 158.93	dysprosium 66 Dy 162.50	holmium 67 Ho 164.93	erbium 68 Er 167.26	thulium 69 Tm 168.93	ytterbium 70 Yb 173.04		
		actinium 89 Ac [227]	thorium 90 Th 232.04	protactinium 91 Pa 231.04	uranium 92 U 238.03	neptunium 93 Np [237]	plutonium 94 Pu [244]	americium 95 Am [243]	curium 96 Cm [247]	berkelium 97 Bk [247]	californium 98 Cf [251]	einsteinium 99 Es [252]	fermium 100 Fm [257]	mendelevium 101 Md [258]	nobelium 102 No [259]		



\* Lanthanide series

lanthanum 57 La 138.91	cerium 58 Ce 140.12	praseodymium 59 Pr 140.91	neodymium 60 Nd 144.24	promethium 61 Pm [145]	samarium 62 Sm 150.36	europium 63 Eu 151.96	gadolinium 64 Gd 157.25	terbium 65 Tb 158.93	dysprosium 66 Dy 162.50	holmium 67 Ho 164.93	erbium 68 Er 167.26	thulium 69 Tm 168.93	ytterbium 70 Yb 173.04
actinium 89 Ac [227]	thorium 90 Th 232.04	protactinium 91 Pa 231.04	uranium 92 U 238.03	neptunium 93 Np [237]	plutonium 94 Pu [244]	americium 95 Am [243]	curium 96 Cm [247]	berkelium 97 Bk [247]	californium 98 Cf [251]	einsteinium 99 Es [252]	fermium 100 Fm [257]	mendelevium 101 Md [258]	nobelium 102 No [259]

\*\* Actinide series

Contaminants (Total amount)	<sup>a</sup> Maximum Allowable Discharge Conc. (mg/L)	<sup>b</sup> Drinking Water Regulations (mg/L)	<sup>b</sup> Public Health Goal (mg/L)
Lead (Pb)	1	0.015	Zero
Copper (Cu)	Not defined	1.3	1.3
Nickel (Ni)	1	Not defined	Not defined
Mercury (Hg)	0.05	0.002	0.002
Cadmium (Cd)	0.1	0.005	0.005
Chromium (Cr)	1.5	0.1	0.1
Arsenic (As)	0.5	0.01	zero

Sources to wastewater:

- Batteries
- Mining industry
- Petrochemical industry
- Manufacture

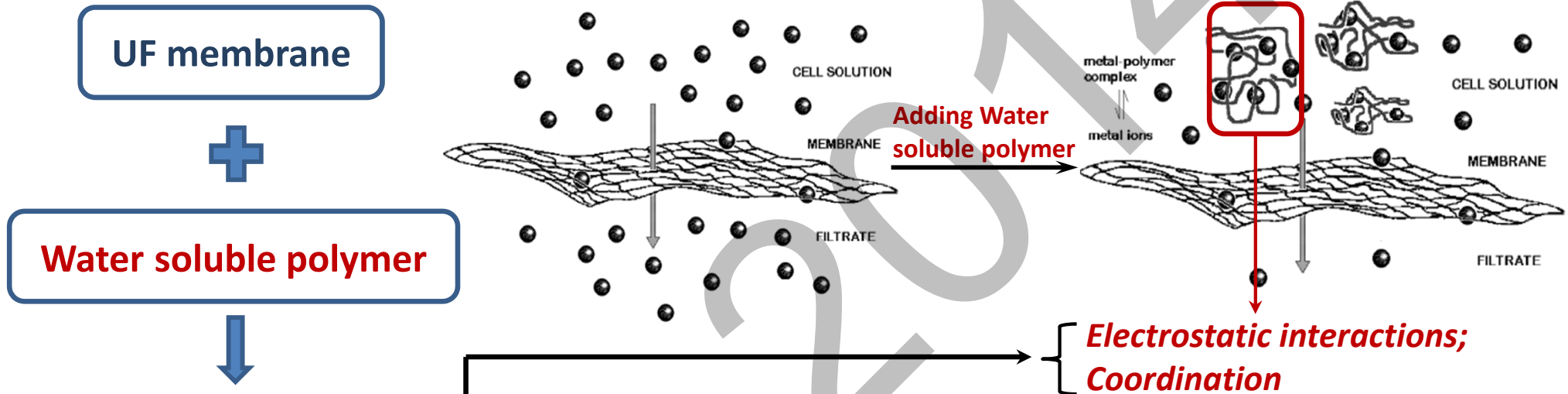
a: National Standard of the P.R.China Integrated Wastewater Discharge Standard

b: National Primary Drinking Water Regulations from USEPA



# Introduction

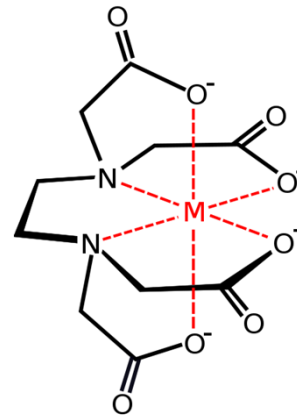
## Polymer-enhanced ultrafiltration (PEUF)



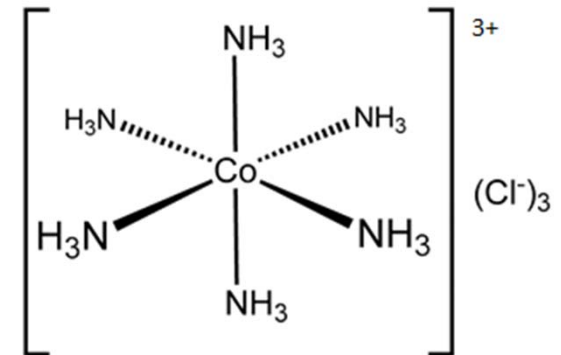
- High content of **Functional Groups**
- Molecular weight greater than the MWCO of UF membranes
- Sufficient solubility in aqueous solution

MWCO: Molecular Weight Cut-Off;  
EDTA: Ethylenediaminetetraacetic acid

Coordination examples:



Metal-EDTA complex



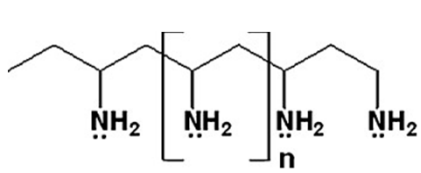
Cobalt(III) complex



# Results and discussion

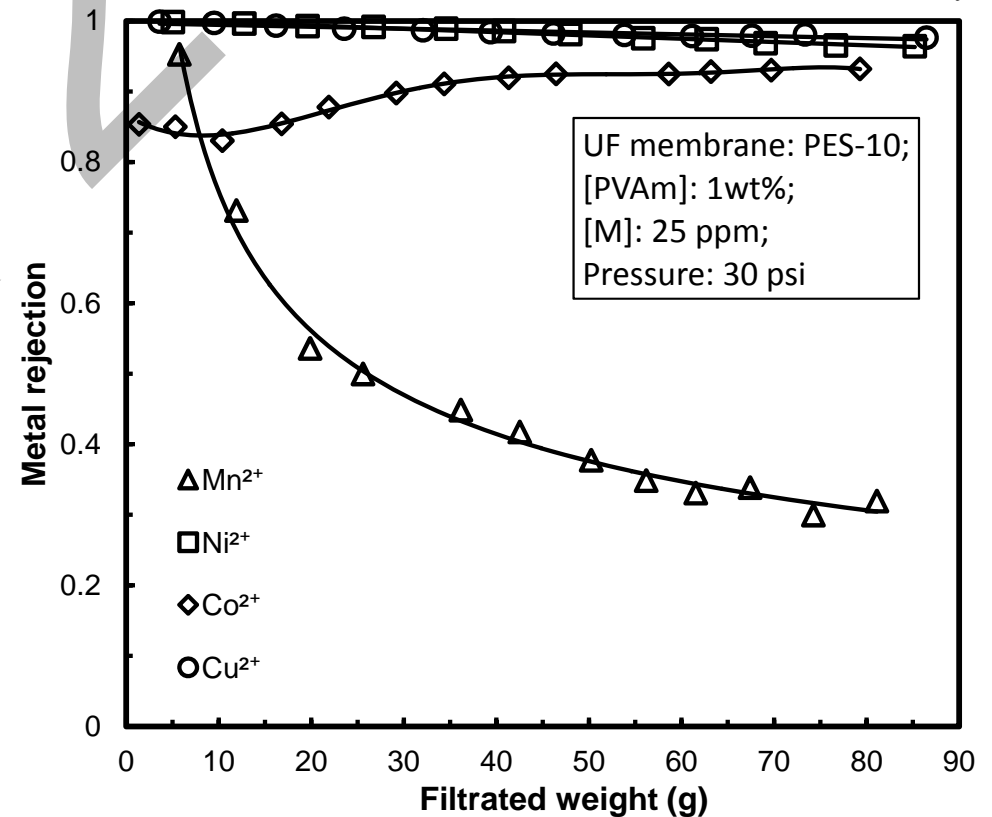
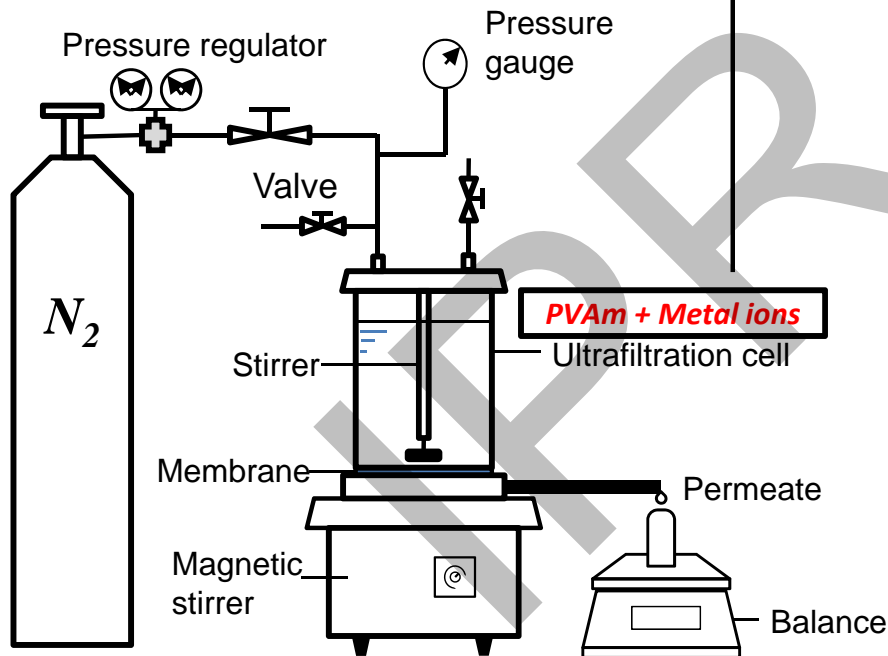
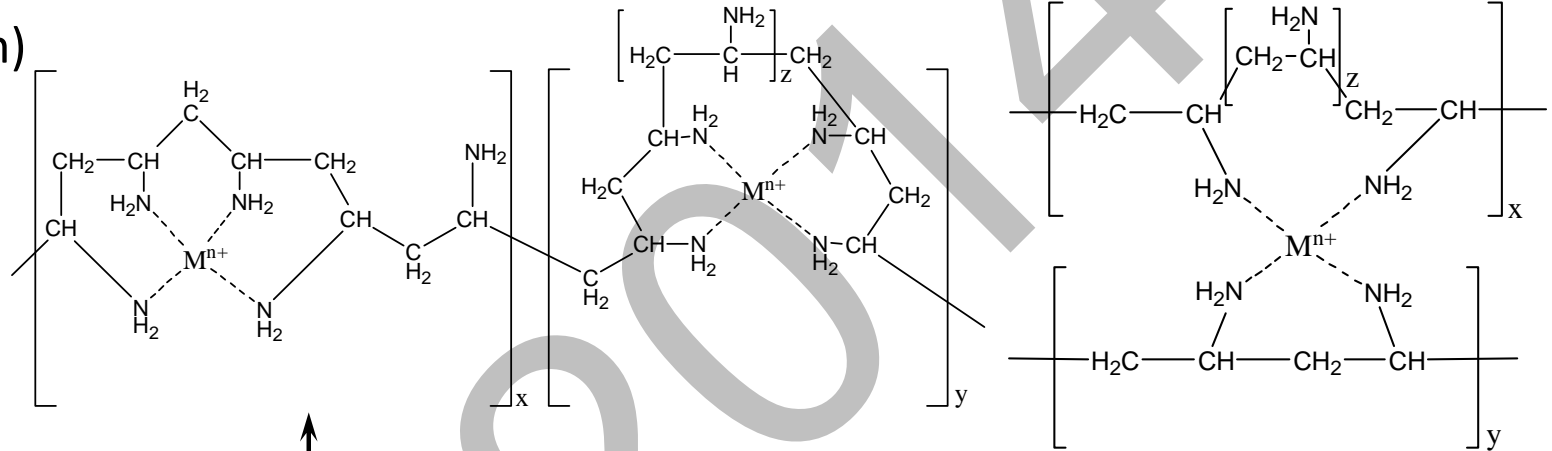
## Metal removal by PVAm-enhanced UF

Polyvinylamine (PVAm)



Lupamin 9095 (BASF);

$\overline{M}_n$ : 340,000





# Summary

- Polyvinylamine is proved to work for heavy metal removal using PEUF
  - Metal rejection, Co<sup>2+</sup>: 89.0%, Cu<sup>2+</sup>: 99.3%, Ni<sup>2+</sup>: 98.8%, Mn<sup>2+</sup>: 40% ([PVAm]: 1wt%, [metals]: 25ppm)
- The metal rejections in PEUF are highly related to the coordination interactions between PVAm and heavy metals
- Potential application in the separation of mercury and arsenic from wastewater



**Thank you !**

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