Examples of Directions and Requirement for Industrial Desalination

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Multi-State Salinity Coalition
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UNIVERSITY OF ARKANSAS

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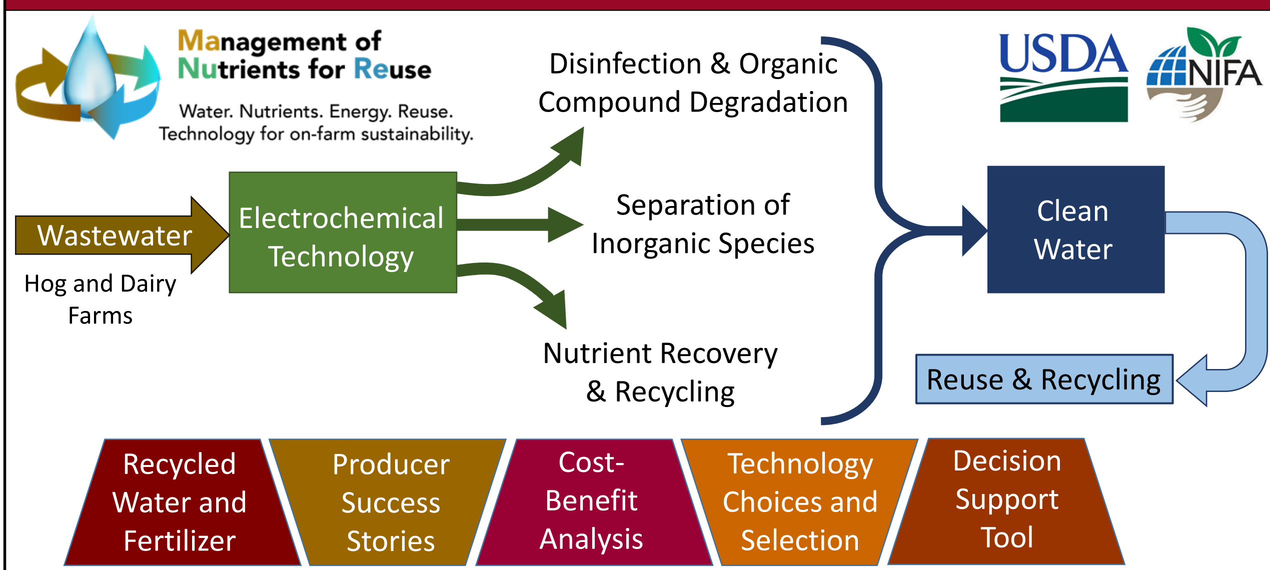
MaNuRe Project: Can we Enable Water and Nutrient Recycling?



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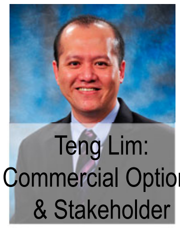
INFEWS / NIFA AFRI Leadership Team


Teng Lim: Commercial Options & Stakeholder Engagement


Kris Brye: Agronomy


Lauren Greenlee: Electrochemistry & Struvite Precipitation


Greg Thoma: Life Cycle Analysis


Jennie Popp: Economics


Rick Stowell: Commercial Options & Stakeholder Engagement


Julie Renner: Protein Engineering & Precipitation Enhancement


Andrew Herring: Electrochemical Device Design &Modeling/Simulation

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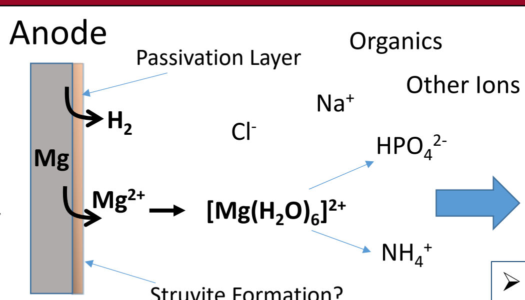
Water Chemistry & Electrochemistry

Hug 2013:
E_{anode}
-1.5 V - -0.6 V



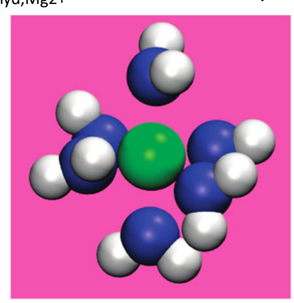
$MgNH_4PO_4 \cdot 6H_2O$

- pH
- Water components & concentrations
- Current/voltage
- Electrode type
- Reactor configuration

E_{anode}	$-E^o = E_{ox}$
$Mg^0 = Mg^{2+} + 2e^-$	2.37 V
$Mg^{2+} = Mg(H_2O)_6^{2+}$	9.5 V

Gibb's Energy of Hydrated Ions

$\Delta G_{hyd,Mg2+}$ = -1940 - -1830 kJ/mol


Mg^{2+} - 1st solvation shell: Octahedral structure, 6 H_2O molecules

$$\Delta G = -nF\Delta E_{cell}$$

n = # electrons; F = Faraday constant

Y. Marcus. *J. Chem. Soc. Faraday Trans.*, 1991, 87(18), 2995-2999.
K.M. Callahan et al. *J. Phys. Chem. A*, Vol. 114, No. 15, 2010.

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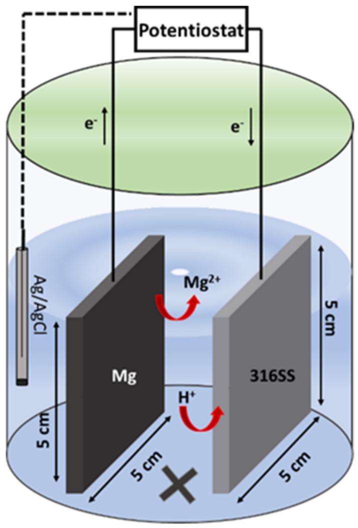
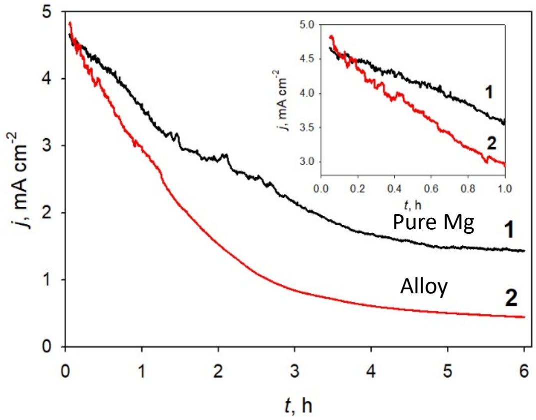
Electrochemical Struvite Formation





- Pure Mg electrode produces more current and more struvite than alloy
- Pure Mg is more expensive than alloy – capital vs. operational cost trade-off

Anode	pH_i [a]	pH_f [b]	$m_{t,current}$ [c] (g)	j [d] (mA cm^{-2})	Struvite (g)
Pure-Mg	4.6±0.1	6.1±0.05	0.269±0.05	1.7±0.3	1.8±0.4
AZ31B	4.5±0.1	5.9±0.06	0.149±0.02	0.6±0.2	0.4±0.1

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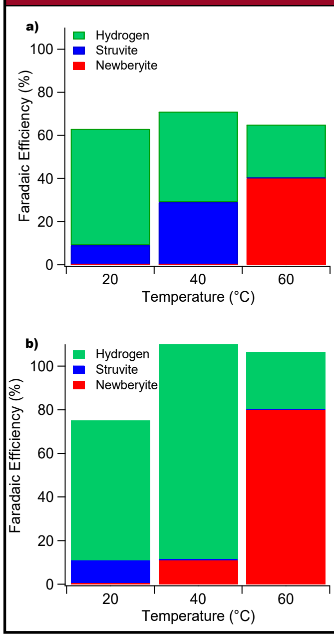
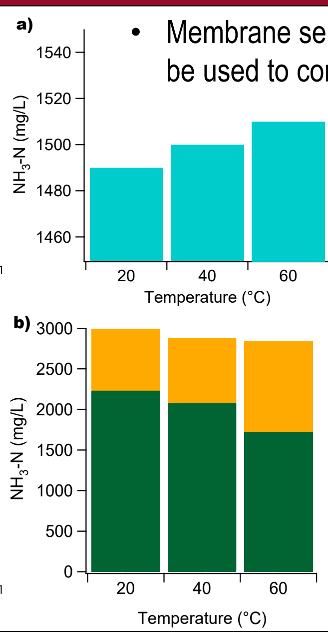
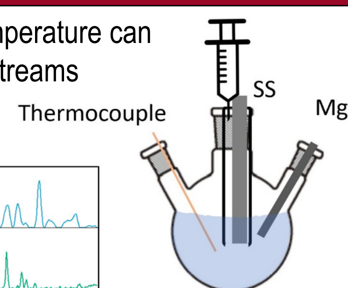
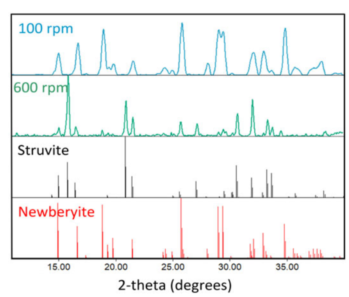
Membrane Separation and Temperature Allow Control of Nutrients

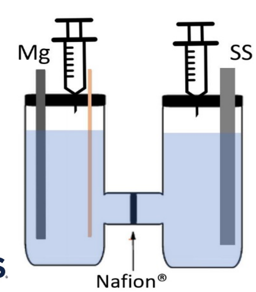




- Membrane separation, flow, and temperature can be used to control nutrient product streams







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Key Takeaways and Talking Points

- Electrochemical nutrient recovery: Reactor and electrode configuration/optimization is important
- Use electrochemical engineering to produce different reusable nutrient/resource streams (driven by stakeholder needs)
- Efforts focus on electrochemistry, water chemistry, engineering design within framework of technoeconomic analysis and scalability
- Opportunity is to look at contaminants as resources and think about how we can use engineering technology in different ways to recycle and reuse / produce useful product streams
- Opportunities to have recovery of energy, fuels, water, and other resources.

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Membrane-Based Concentration of Ammonium and Phosphate

Goals:

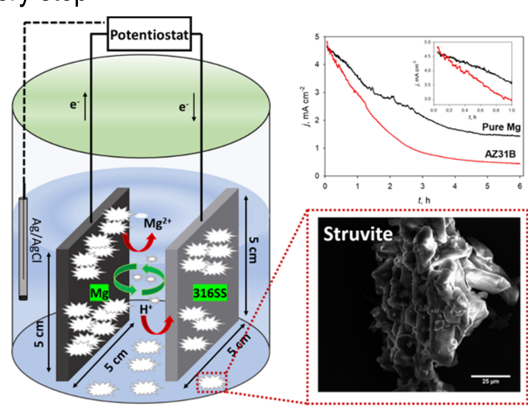
❖ Pre-concentration/recovery step of nutrients

❖ Enhance ammonium and phosphate in a struvite recovery step

Industrial or Municipal WW →

- NH_4^+ Rejection → $H_2PO_4^-$ / HPO_4^{2-} Rejection
- NH_4^+ & $H_2PO_4^-$ / HPO_4^{2-} Rejection

→



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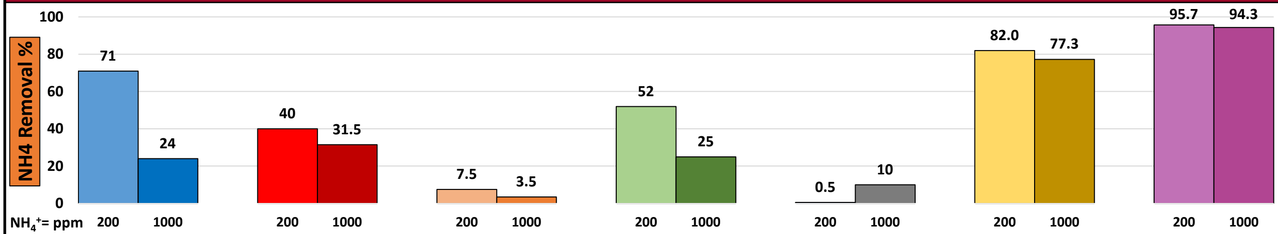
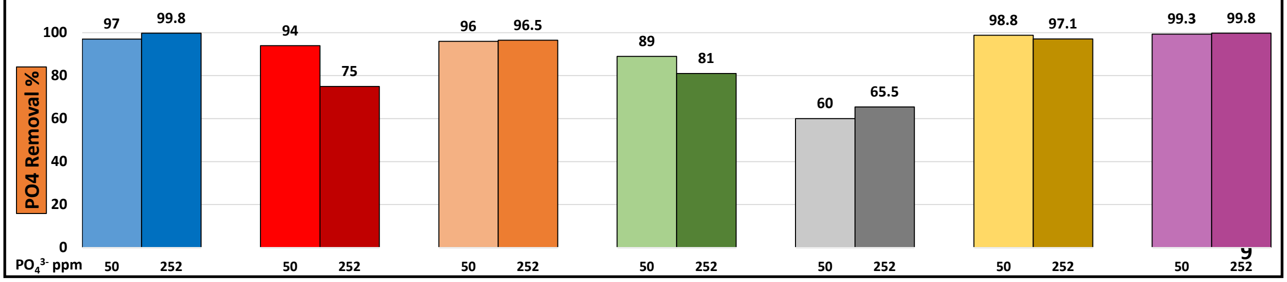
Short Term Studies: Removal of Phosphate and Ammonium



- Evaluation of commercially-available membranes
- Results suggest a two-step membranes in series setup for concentration of phosphate, then ammonium



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Key Takeaways and Talking Points

- Pre-concentration of ammonium and phosphate would enable more efficient electrochemical nutrient recovery / struvite production
- Membranes in series to separately concentrate phosphate, then ammonium would allow two separate streams of concentrated nutrients & prevent struvite formation in pipes
- Will need to test and optimize with real wastewaters
- Need to understand performance issues in complex water chemistries
- Applications in industry include food production and processing operations, wastewater treatment, and liquid wastes from agriculture
- Currently testing commercial membranes – may progress to experimental membranes

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