Metropolitan Water Reclamation District of Greater Chicago

Welcome to the May Edition of the 2025 M&R Seminar Series

NOTES FOR SEMINAR ATTENDEES

- Remote attendees' microphones are muted at entry to minimize background noise.
  For attendees in the auditorium, please silence your phones.
- A question and answer (Q/A) session will follow the presentation.
- For remote attendees, please use "**Chat**" only to type questions for the presenter. For other issues, please email Pam to SlabyP@mwrd.org.
  For attendees in the auditorium, please raise your hand and wait for the microphone to ask a verbal question during the Q/A session.
- The presentation slides will be posted on the MWRD website after the seminar.
- This seminar is pending approval by the ISPE for one PDH and pending approval by the IEPA for one TCH. Certificates will be issued only to participants who attend the entire presentation.

Nancy G. Love, Ph.D., P.E., BCEE
JoAnn Silverstein Distinguished University Professor
Borchardt and Glysson Collegiate Professor
Department of Civil and Environmental Engineering
University of Michigan

Dr. Love is a Distinguished Professor with the Department of Civil and Environmental Engineering, University of Michigan. In collaboration with her students, Professor Love works at the interface of water, infrastructure, environmental quality, and public health in both domestic and global settings. The group is focused on understanding how engineering design and operation of water systems influence sustainability and access to water services and advancing methods to achieve a circular nutrient economy. Dr. Love is a licensed professional engineer in the State of Michigan and a Board Certified Environmental Engineer. She has held leadership positions in multiple organizations, including the Water Environment Federation, the International Water Association, and the Association of Environmental Engineering and Science Professors, and is a Fellow of all three.

Achieving Nutrient Efficiency and Improving Treatment Capacity through Source Separation

Nancy Love
University of Michigan

Metropolitan Water Reclamation
District of Greater Chicago
May 30, 2025

n-e-wcycles.org

NSF Convergence Accelerator

asset recycling our nutrients

2024-2025

Nancy Love
Technical Design & PI
Professor, Civil & Environmental Engr,
University of Michigan

Jamina Shupack
Community Education & Project Management, Executive Director
The Rich Earth Institute

Marisa Manheim
User-Centered Design
Asst Professor, Environment & Sustainability, University at Buffalo

Mathew Lippincott
Regulatory and Policy Consultant,
University of Michigan

Engines

2024-

GREAT LAKES ReNEW

David Lampert (co-PI)
Asst Professor
Civil & Environmental Engineering
Illinois Tech

Nancy Love (co-PI)
Professor
Civil & Environmental Engineering
University of Michigan

RICH EARTH INSTITUTE

BRIGHTWATER TOOLS
Technologies for Regenerative Sanitation

INFEWS

2016-2022

UNIVERSITY OF MICHIGAN

New Water ReSources

University at Buffalo

HRSD
Cleaning wastewater every day for a better Bay.

RICH EARTH INSTITUTE

(>20 collaborators across the 4 year project)

EPA

2014-2016

THE Water Research FOUNDATION

RICH EARTH INSTITUTE

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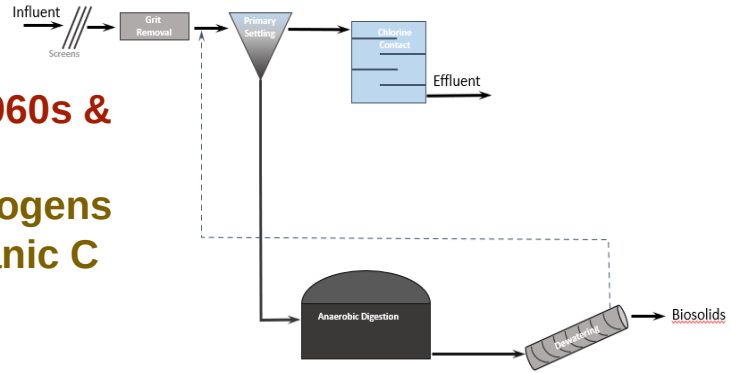
Brown AND Caldwell

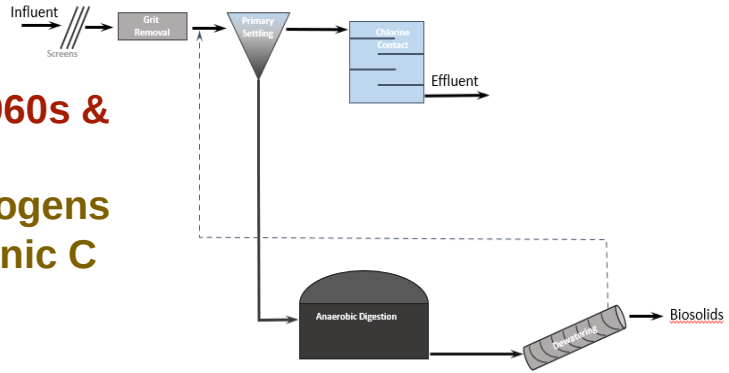
Evolution in the water industry centers around a common backbone



Circa 1960s & earlier

- **Pathogens**
- **Organic C**

Evolution in the water industry centers around a common backbone



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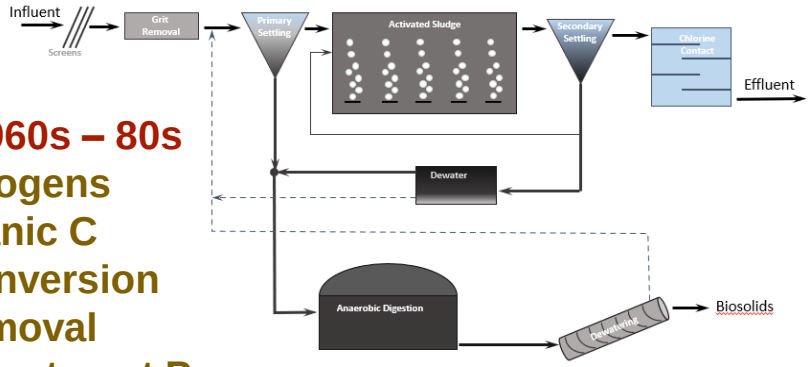
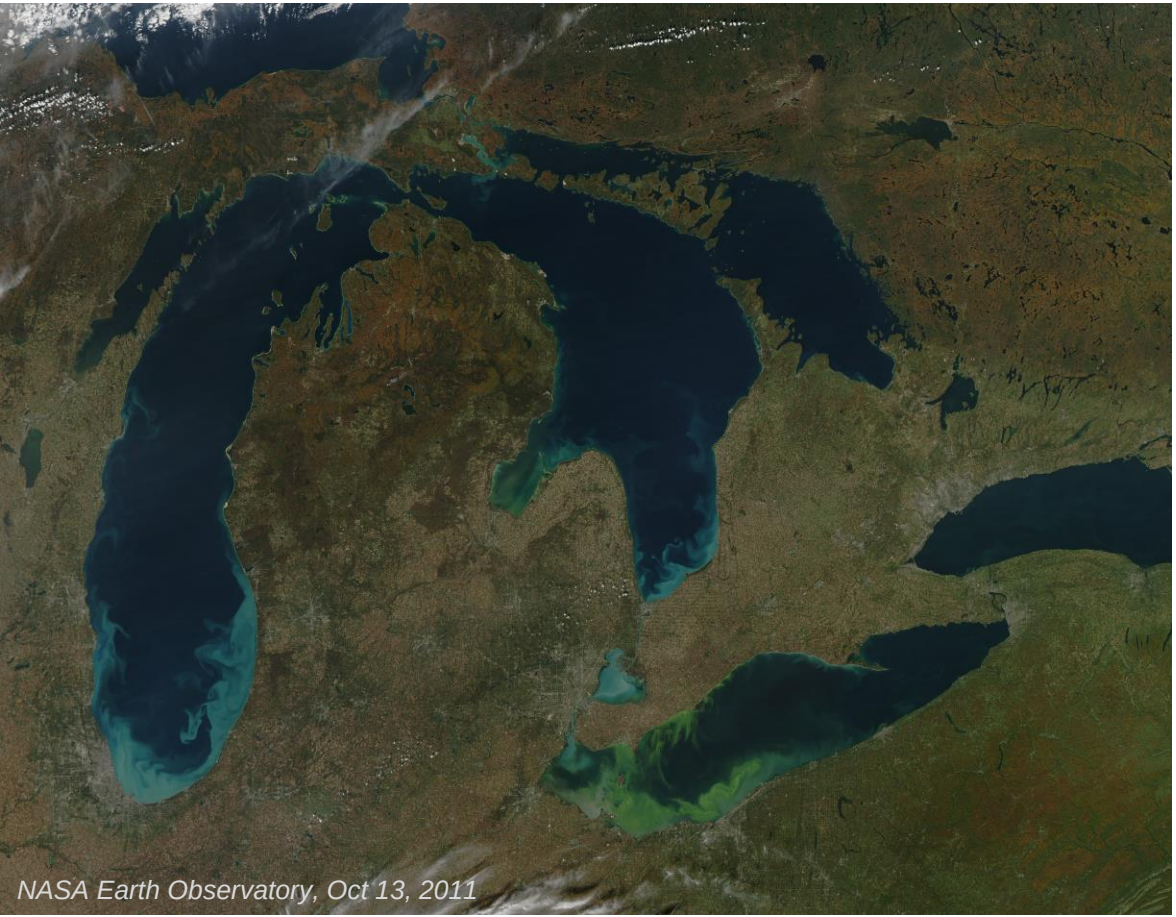
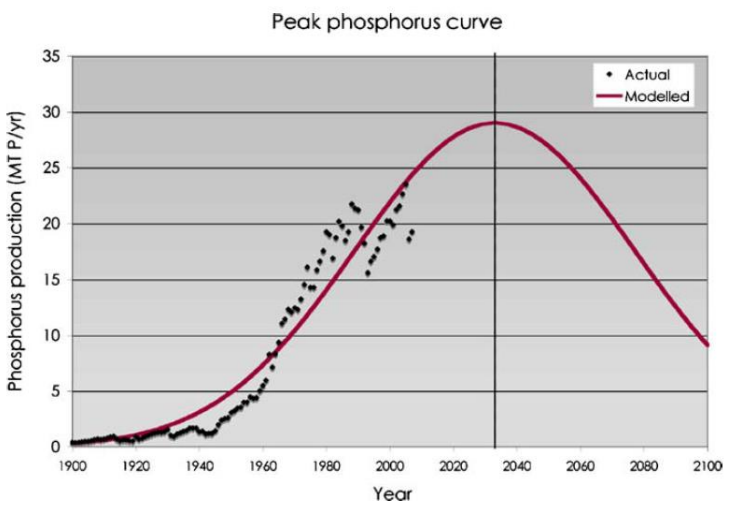


Circa 1960s – 80s

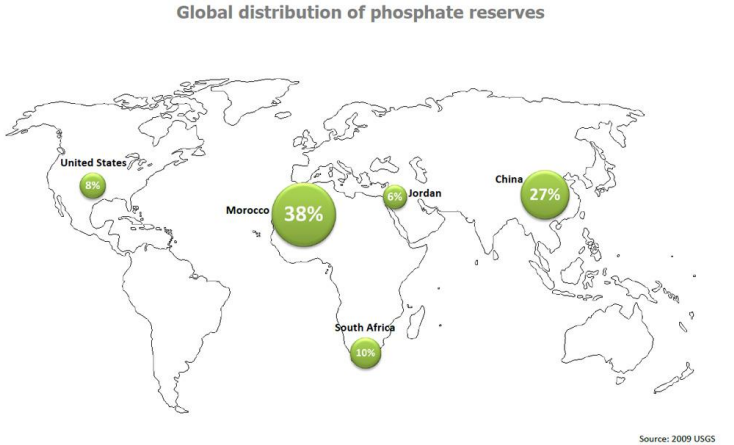
- Pathogens
- Organic C
- N conversion
- P removal
- Pretreatment Programs

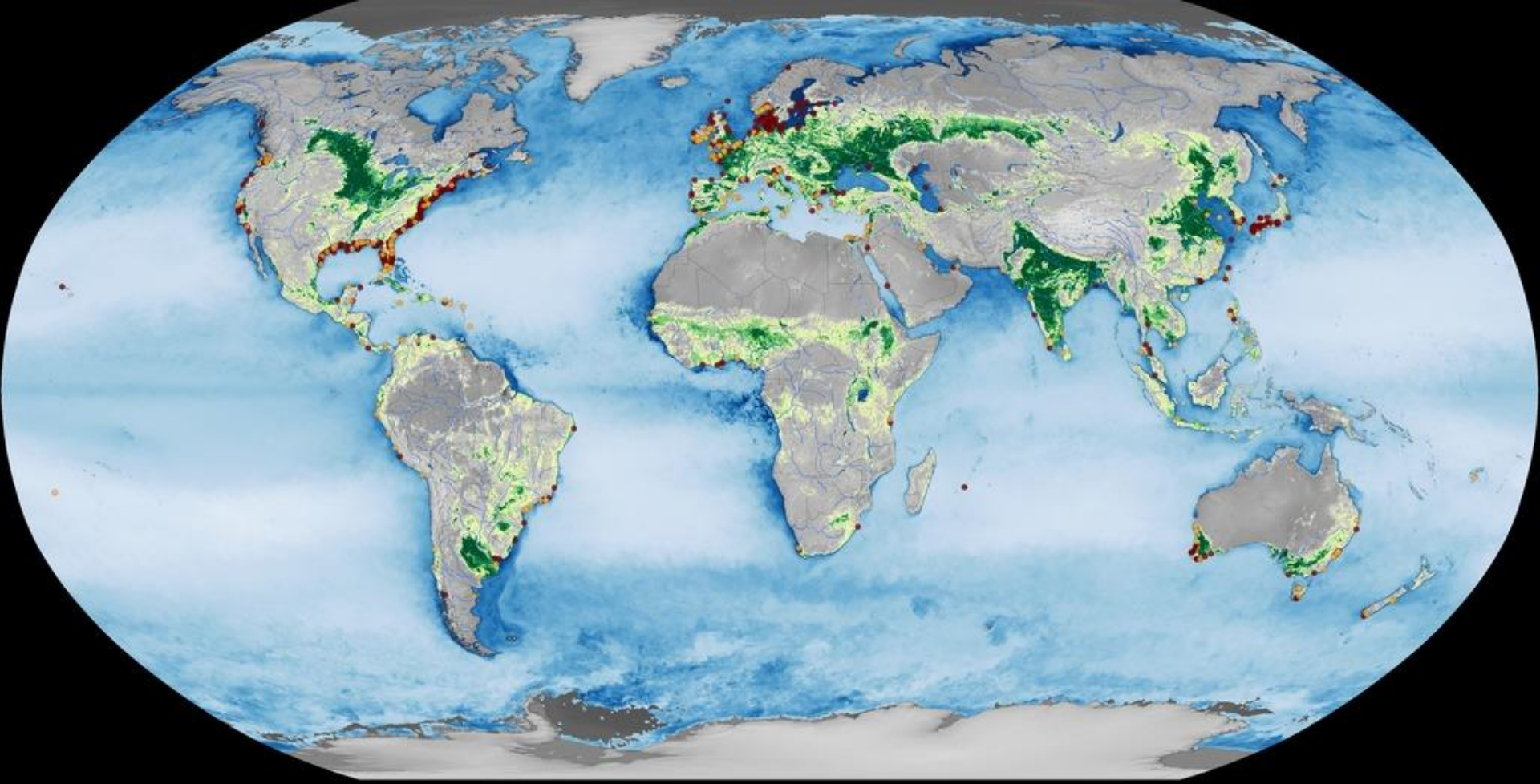


NASA Earth Observatory, Oct 13, 2011



Cordell et al., *Global Environmental Change* (2009)




Particulate Organic Carbon (mg/m³)
10 20 50 100 200 500 1,000
Eutrophic Zone
Hypoxic Zone
Croplands (% of Land Area)
0 100
NASA Scientific Visualization Studio, https://svs.gsfc.nasa.gov/30479/

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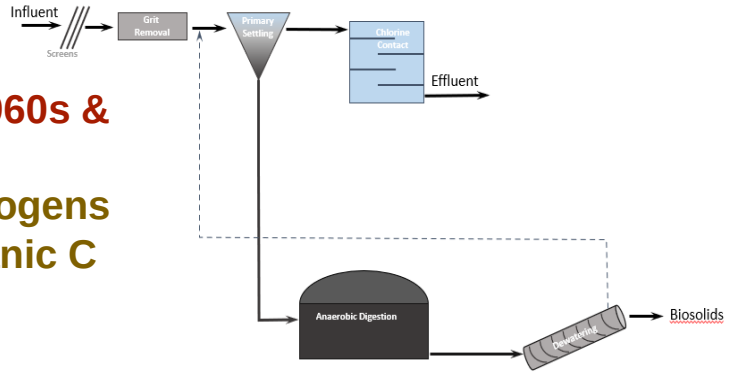

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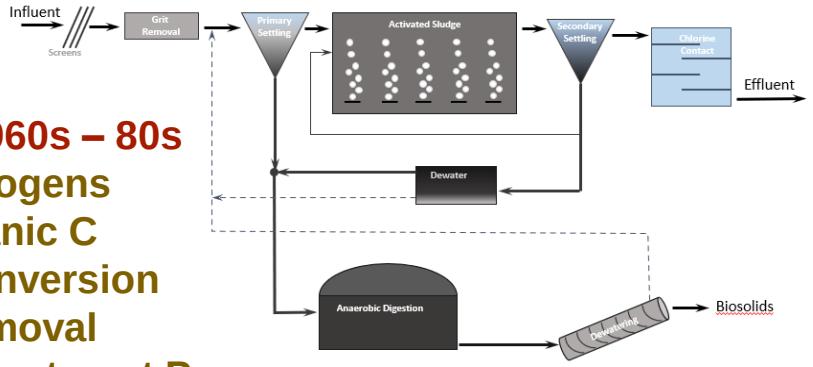

Circa 1990s & 2000s

- Pathogens
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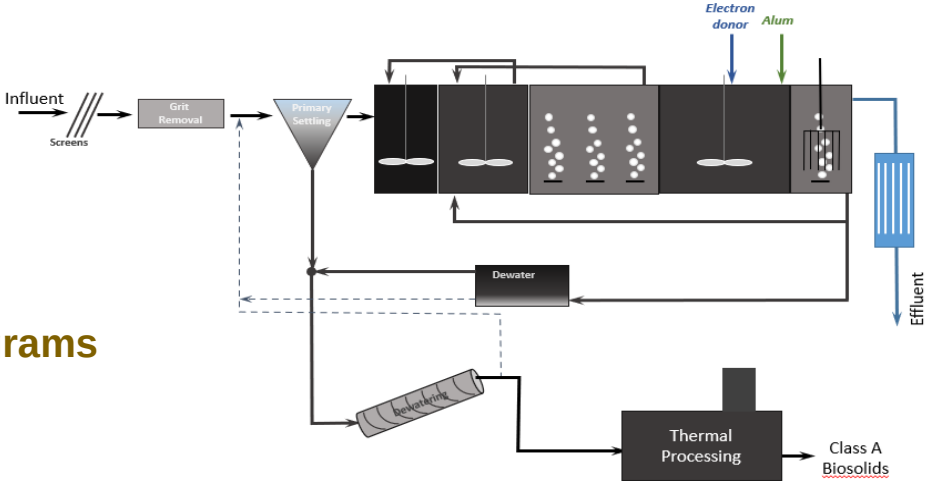
- Water reuse
- Class A Biosolids



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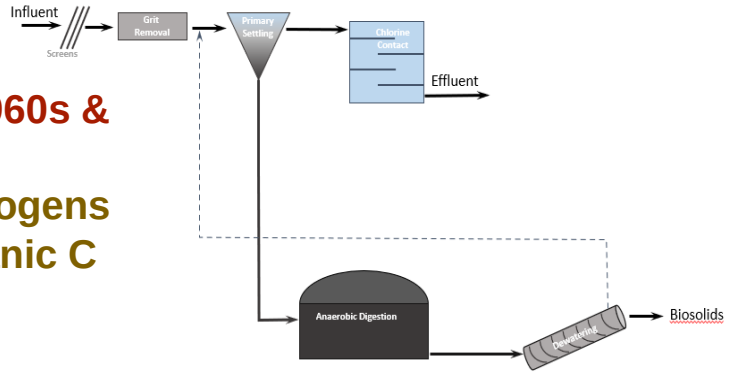

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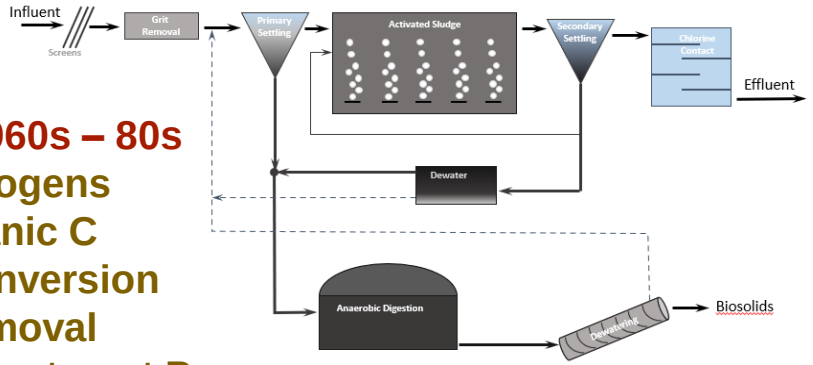

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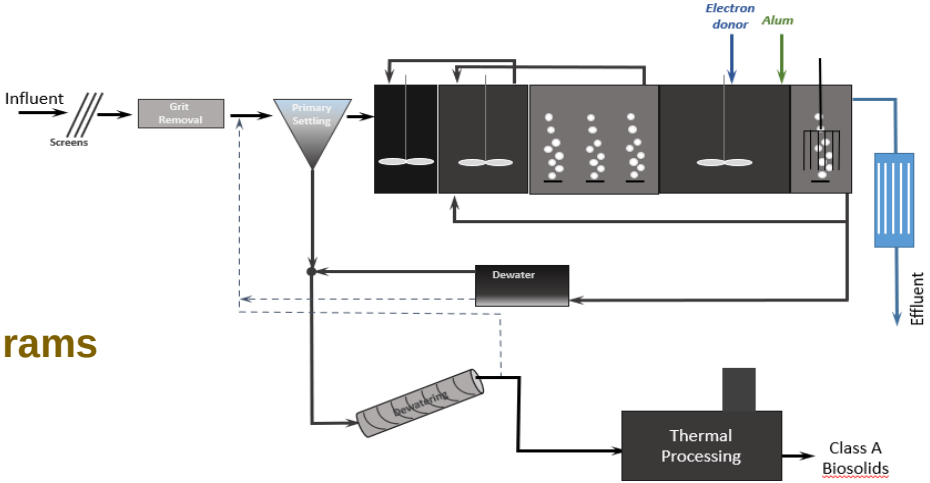

Circa 2010s & 2020s: Intensification

- Improved performance
- Reduced energy
- Increased capacity
- Sustainability
- Reduced costs
- All in smaller footprint

Consider these drivers and trends:

The current paradigm of centralized treatment of mixed wastes has achieved high levels of sanitation, industrial treatment, and urban economic prosperity.

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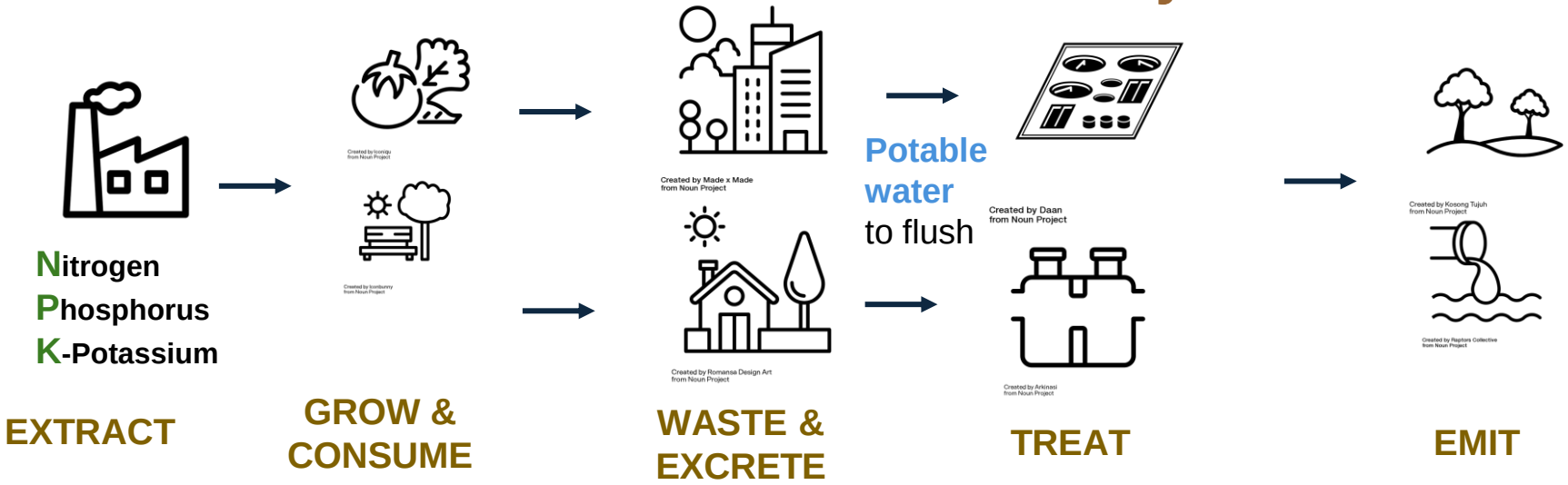
Implementation of innovative technologies in the water sector tends to be driven by urban or resource-rich utilities.

What we start designing today will be with us toward the end of the 21st century

Let’s rethink

resource efficiency

The Current Linear Resource-Inefficient System:



43 kJ/g N: energy to produce N via the Haber Bosch process

29 kJ/g P for mining and extraction

45-109 kJ/g N: energy required to remove the N pollution via mixed flow centralized treatment

45 kJ/g P energy required to remove the P pollution via mixed flow centralized treatment

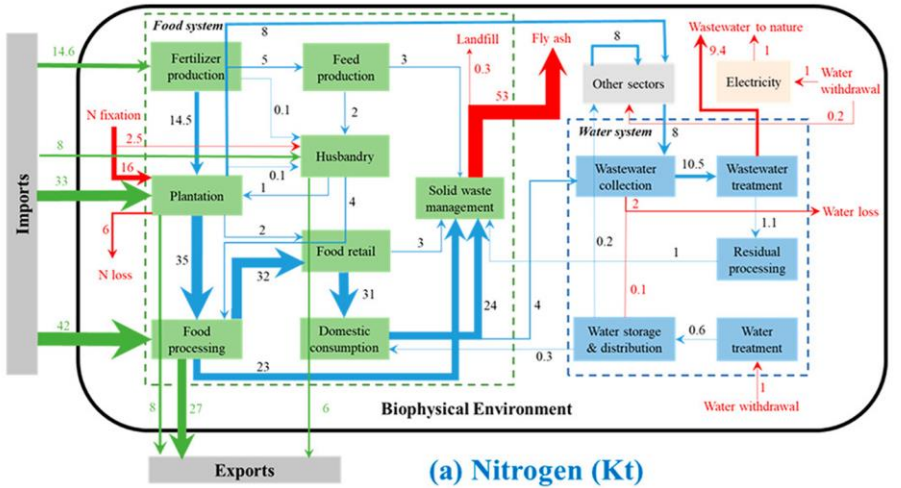
Energy estimates by B. E. Rittmann

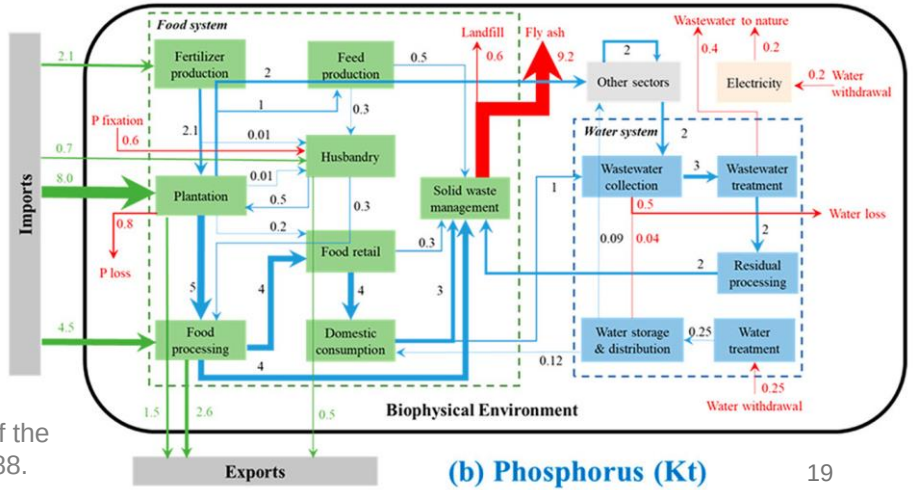
Why is nutrient reduction important for the Great Lakes Region?

What is resource *INEFFICIENCY?*

The vast majority of N & P enters cities as food and leaves as biosolids, solid waste, or effluent.

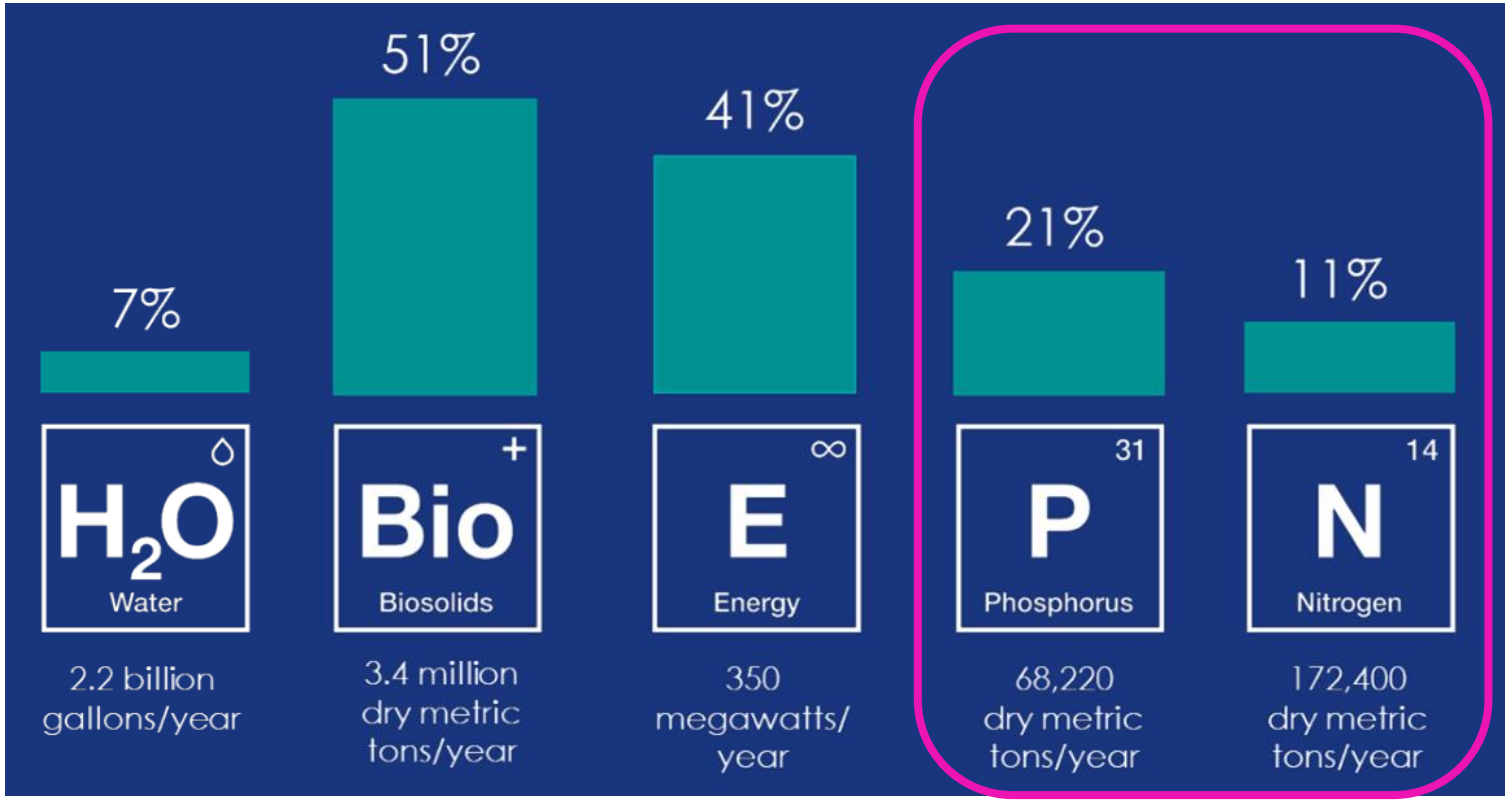
Detroit is typical: 58% of food-related N and 70% of food-related P ends up in the environment in a reactive form.



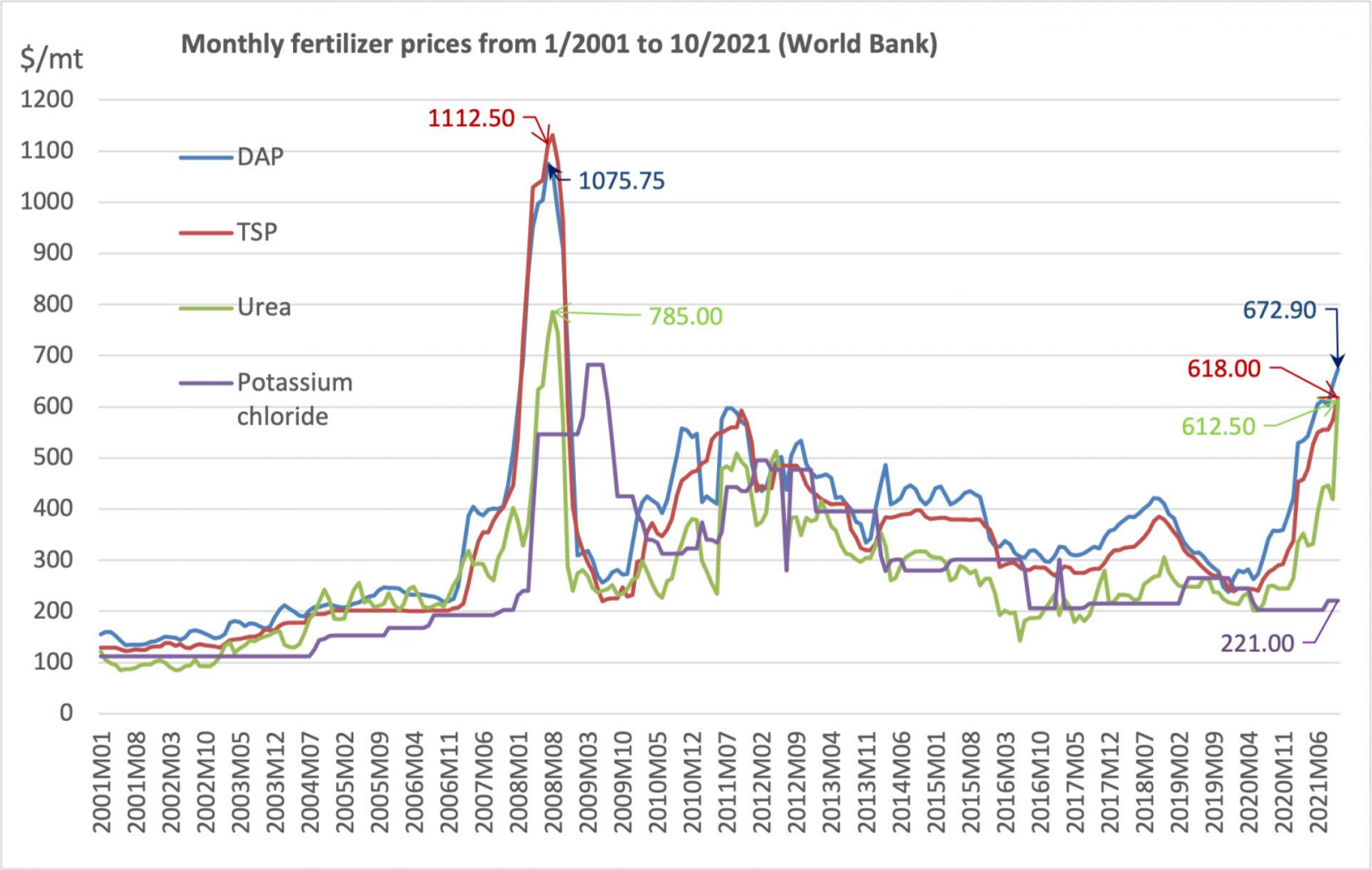


Liang et al. 2019. Quantifying the urban food-energy-water nexus: The case of the Detroit Metropolitan Area. *Environmental Science & Technology*, **53**(2):779-788.

Resources recovered by WRRFs in the U.S.



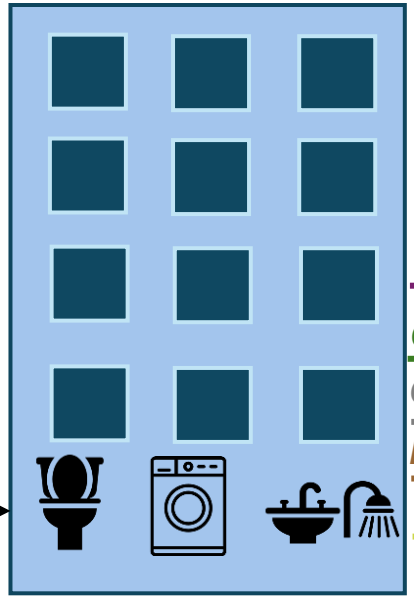
Rauch-Williams et al., 2018. Preparation of Baseline Data to Establish the Current Amount of Resource Recovery.



Beghin and Nogueira, Center for Agricultural Profitability, University of Nebraska, https://cap.unl.edu/crops/perfect-storm-fertilizer-markets

What if……?

What is “wastewater” or used water?



Brines

Grinder output

Gray water

Brown water

Yellow water

Blend into a mixed waste **OR** Source separate

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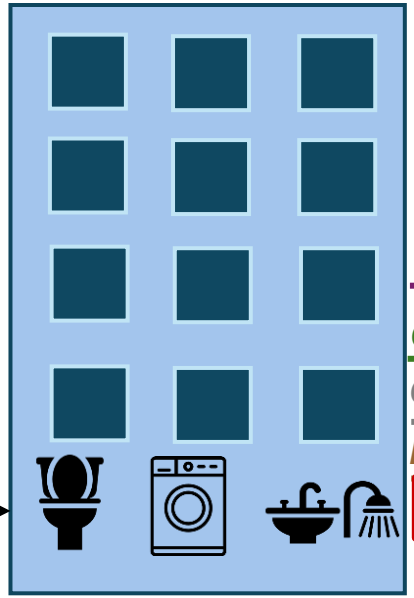

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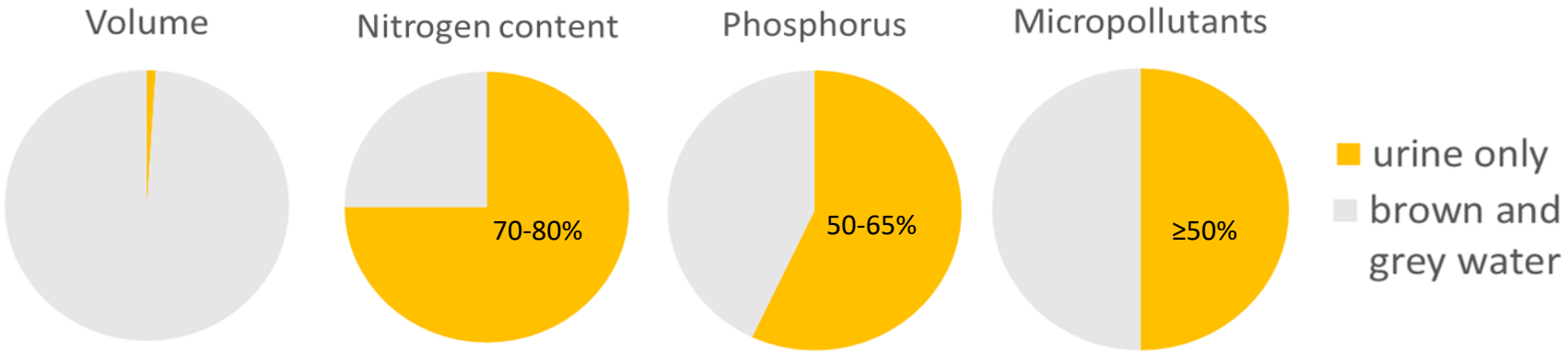
Urine separation supports RESOURCE EFFICIENCY

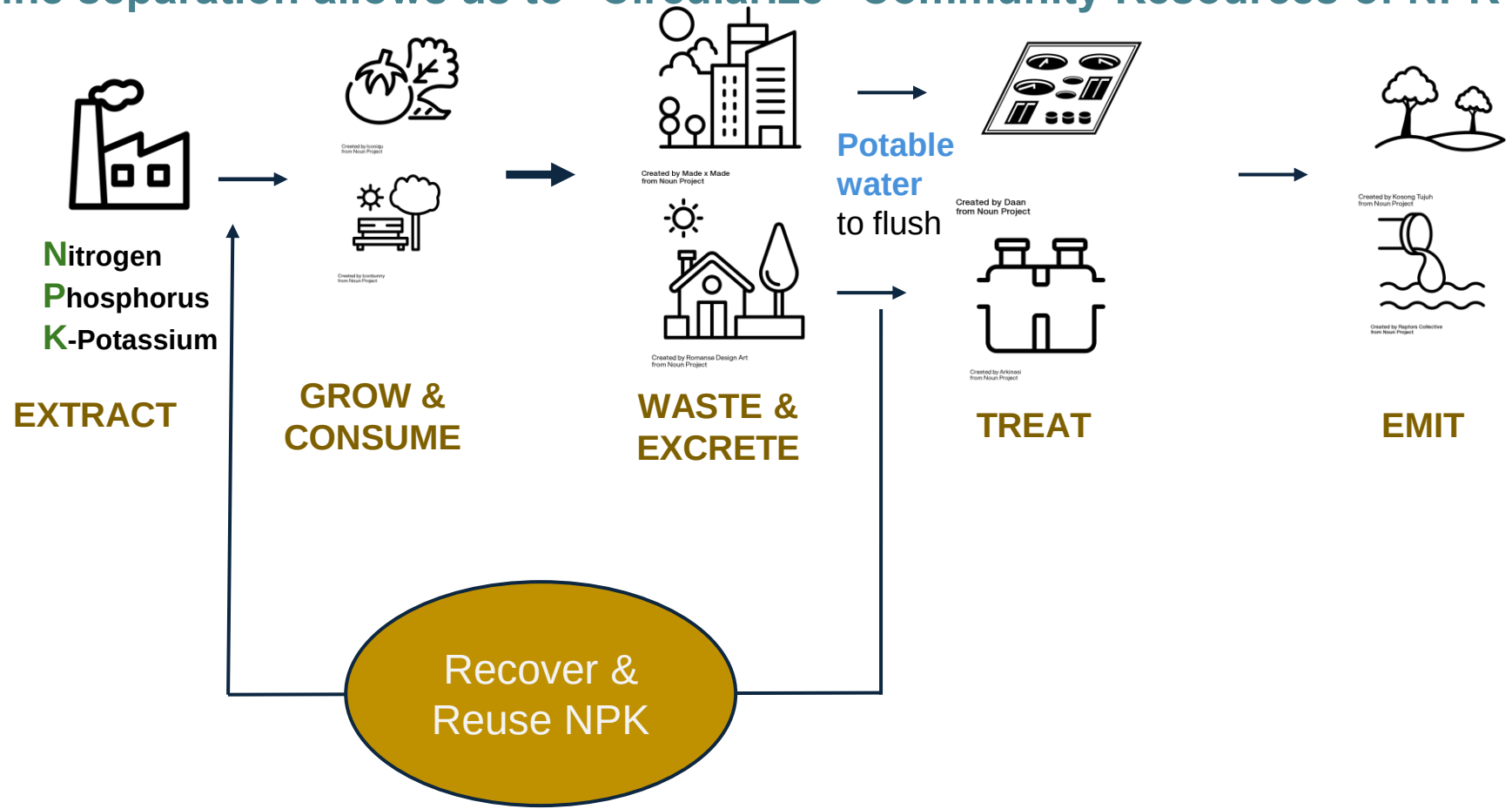
Urine contains most of the nutrients in sewage; separation can offset potable water demand, aeration demand and create a regional fertilizer.



Wastewater	~40 mg N/L	~7 mg P/L	ng/L scale
Urine	~8000 mg N/L	~400 mg P/L	µg/L scale

up to ~20% of household potable water use goes toward flushing

Urine separation allows us to “Circularize” Community Resources of NPK



Sponsored research has supported advancing all aspects of urine recycling since 2015

https://youtu.be/iX1F4dYLF84

LCA & TEA — Value Chain Analysis — Training & Networks

Urine Collection, Plumbing & Transport

Processing

Product Use

Risk Analysis — Regs, Codes, & Standards — Perceptions

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LCA & TEA

Value Chain Analysis

Training & Networks

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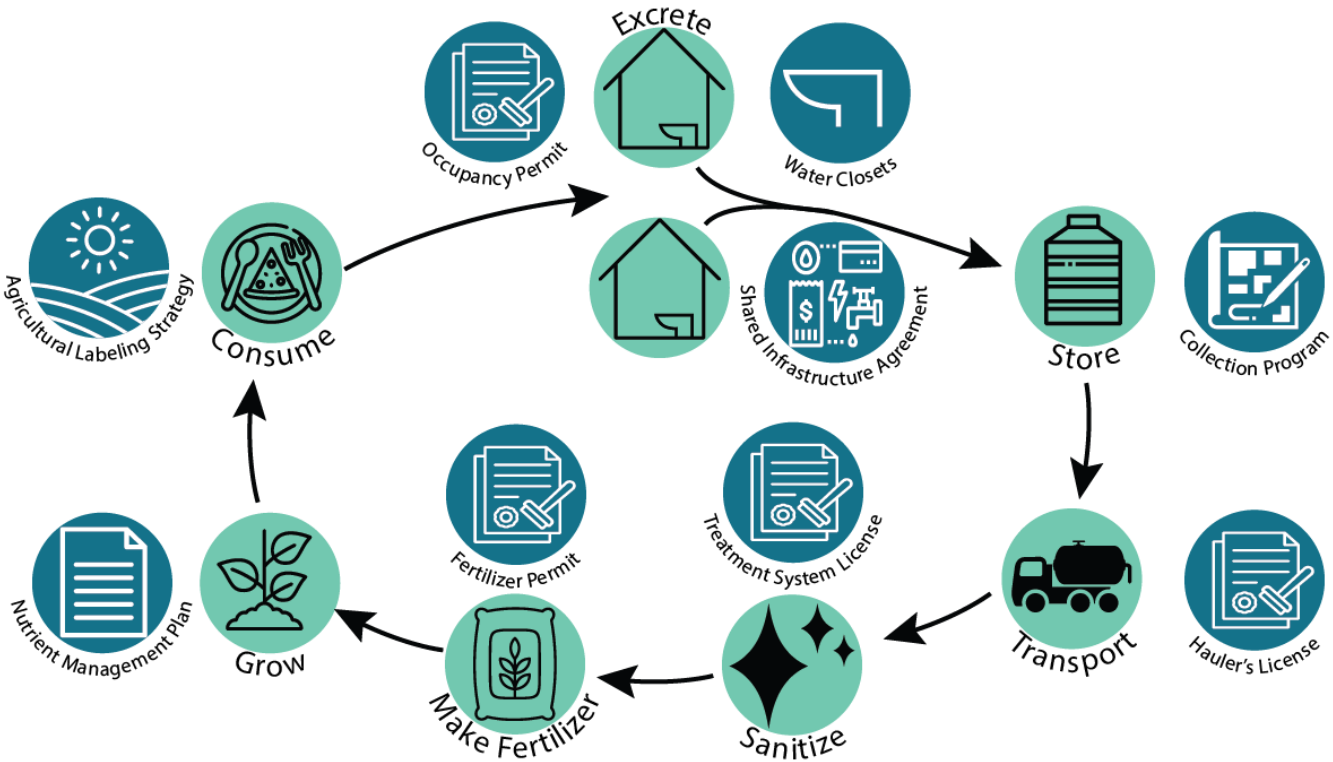
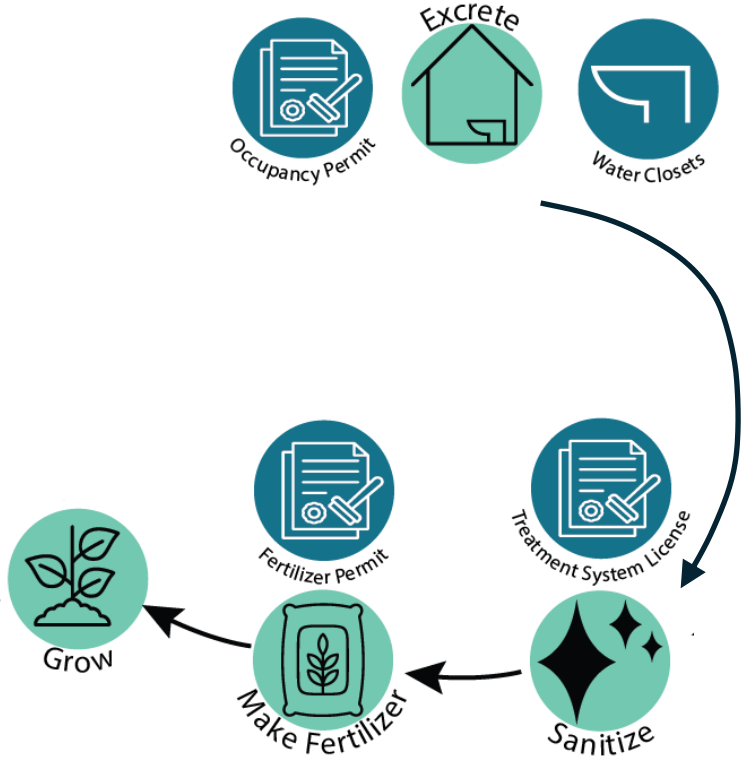
Creating fixture codes and pathways to fertilizer licensing is critical to advancing urine recycling



Work by Mathew Lippincott

We have a research fertilizer license from MDARD for our urine-derived fertilizer to support field trials.



Michigan Department of Agriculture and Rural Development
Bureau of Environment and Sustainability
Commercial Fertilizer Manufacturer's / Distributor's License

ISSUED TO:
U OF M CIVIL & ENVIRONMENTAL ENGINEERING
2350 HAYWARD AVE
ANN ARBOR, MI 48109

ID Number: 004206 License No. 252447
Date Issued: January 3, 2025
Expires: December 31, 2025

FERTILIZER

Mailing Address:
NANCY LOVE
U OF M CIVIL & ENVIRONMENTAL ENGINEERING
2350 HAYWARD AVE
ANN ARBOR, MI 48109

This license is not transferable and is only valid for the establishment and address listed above.
This license issued in accordance with provisions of Act 451 of 1994, as amended, Part 85.

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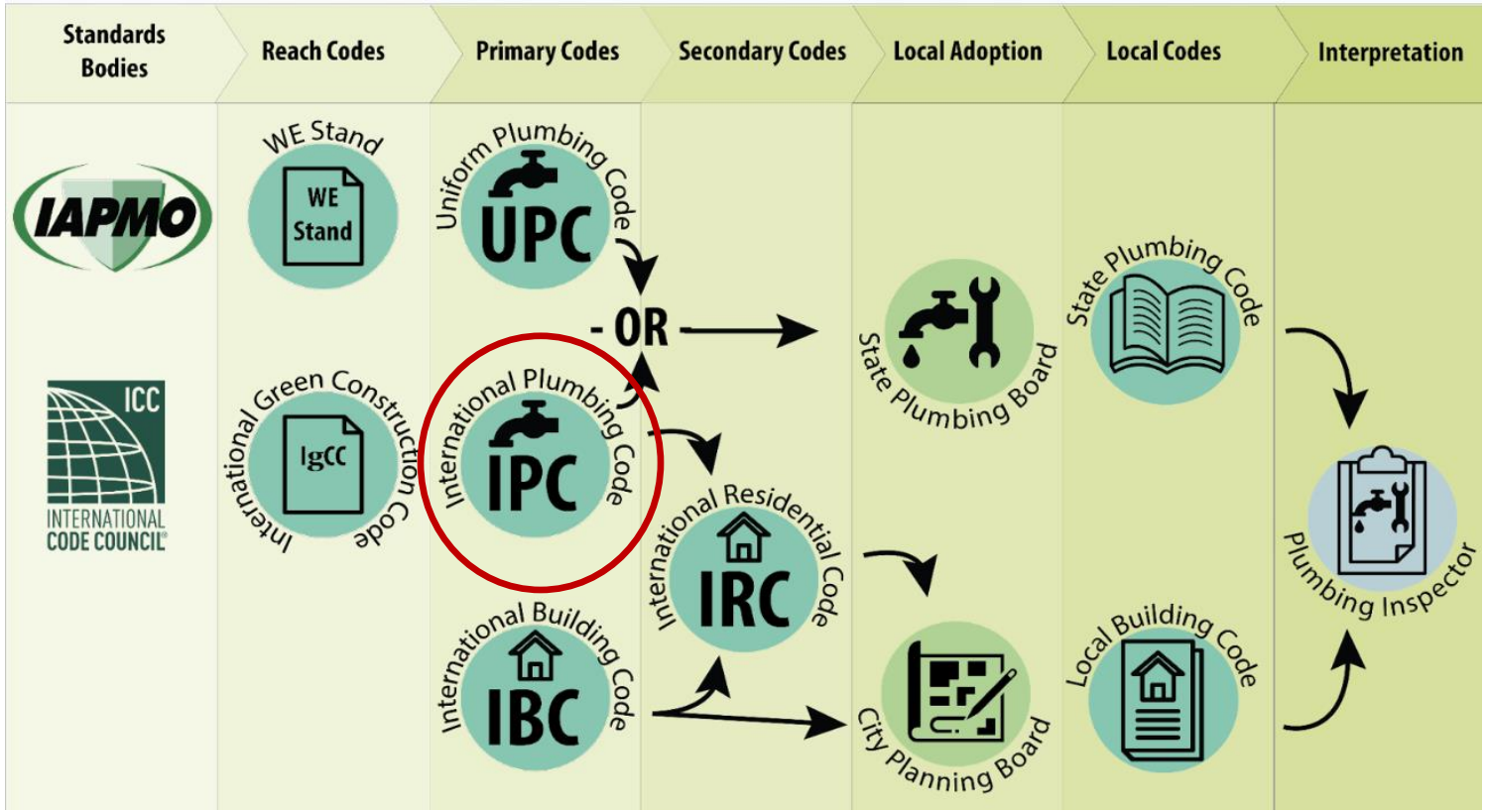

LIXIL

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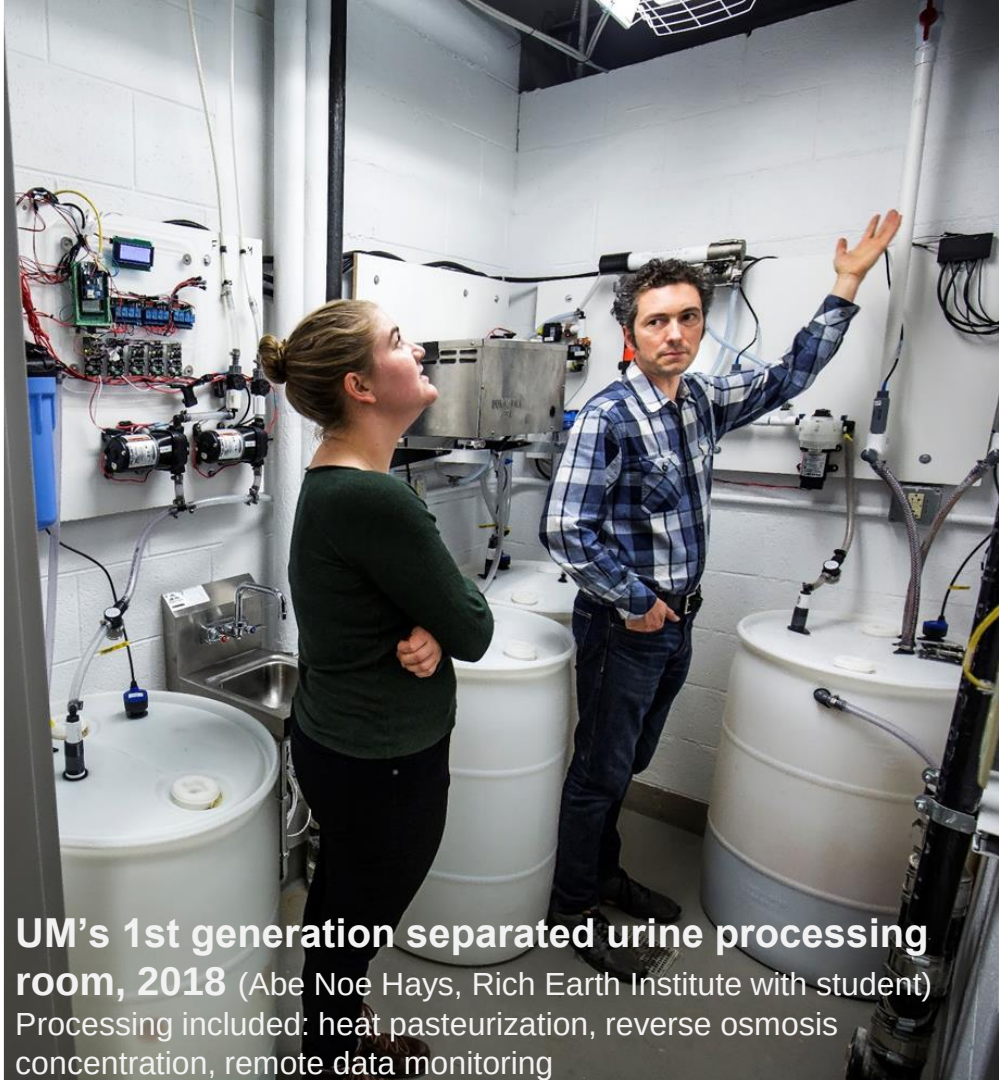
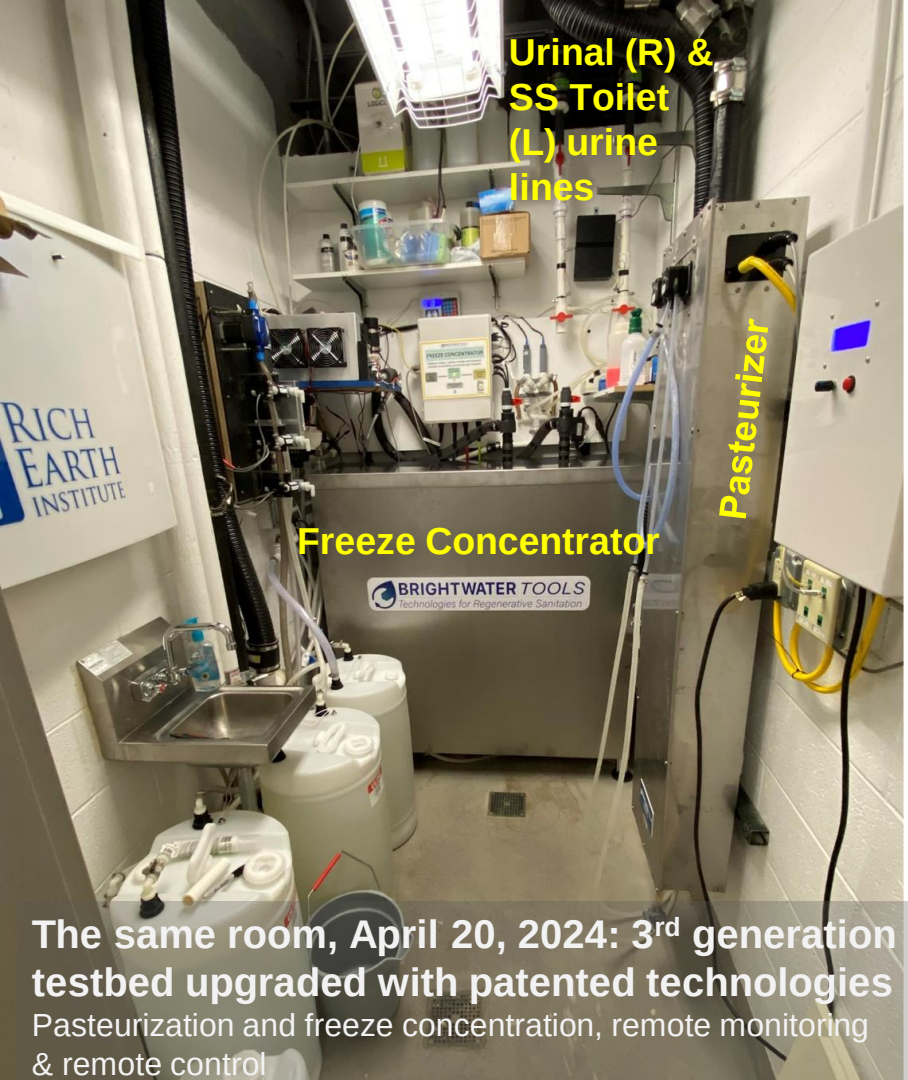
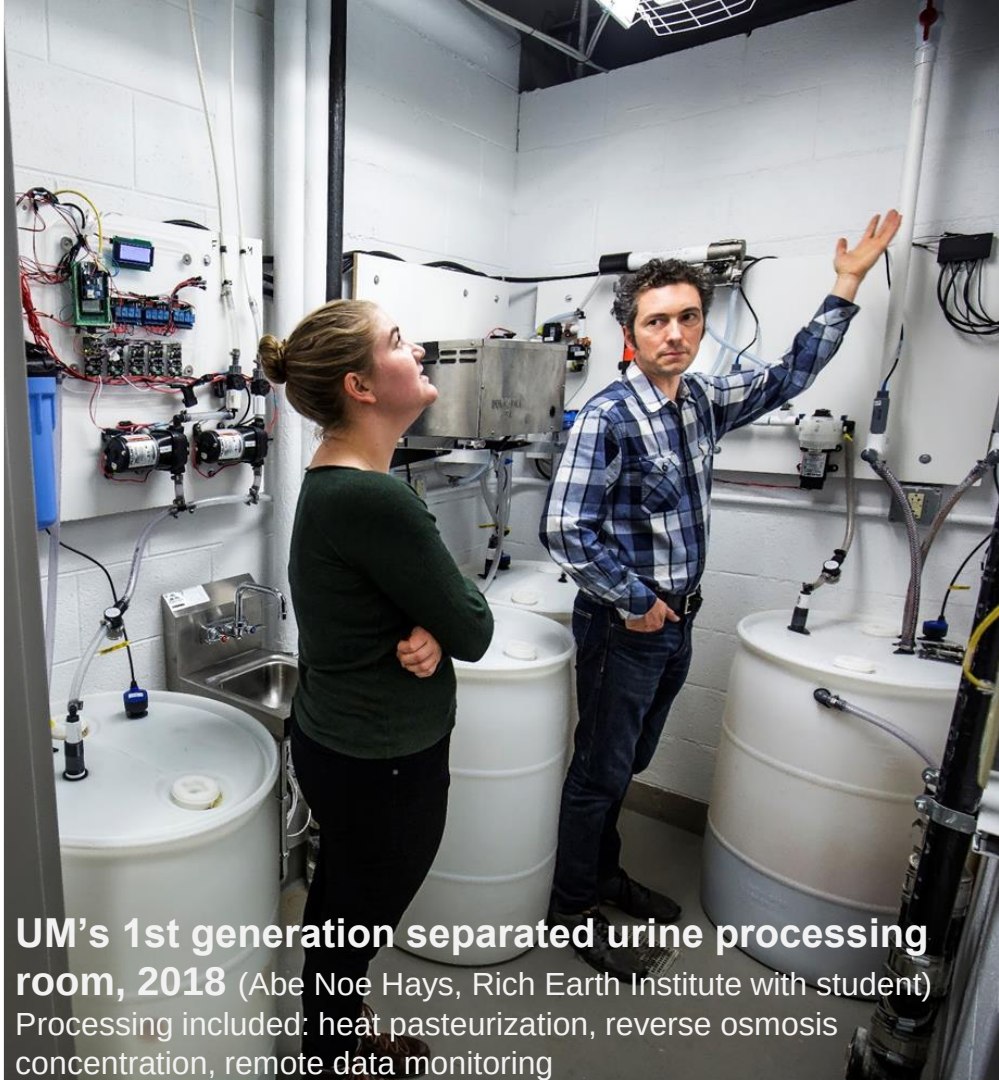


UM’s 1st generation separated urine processing room, 2018 (Abe Noe Hays, Rich Earth Institute with student)
Processing included: heat pasteurization, reverse osmosis concentration, remote data monitoring



The same room, April 20, 2024: 3rd generation testbed upgraded with patented technologies
Pasteurization and freeze concentration, remote monitoring & remote control



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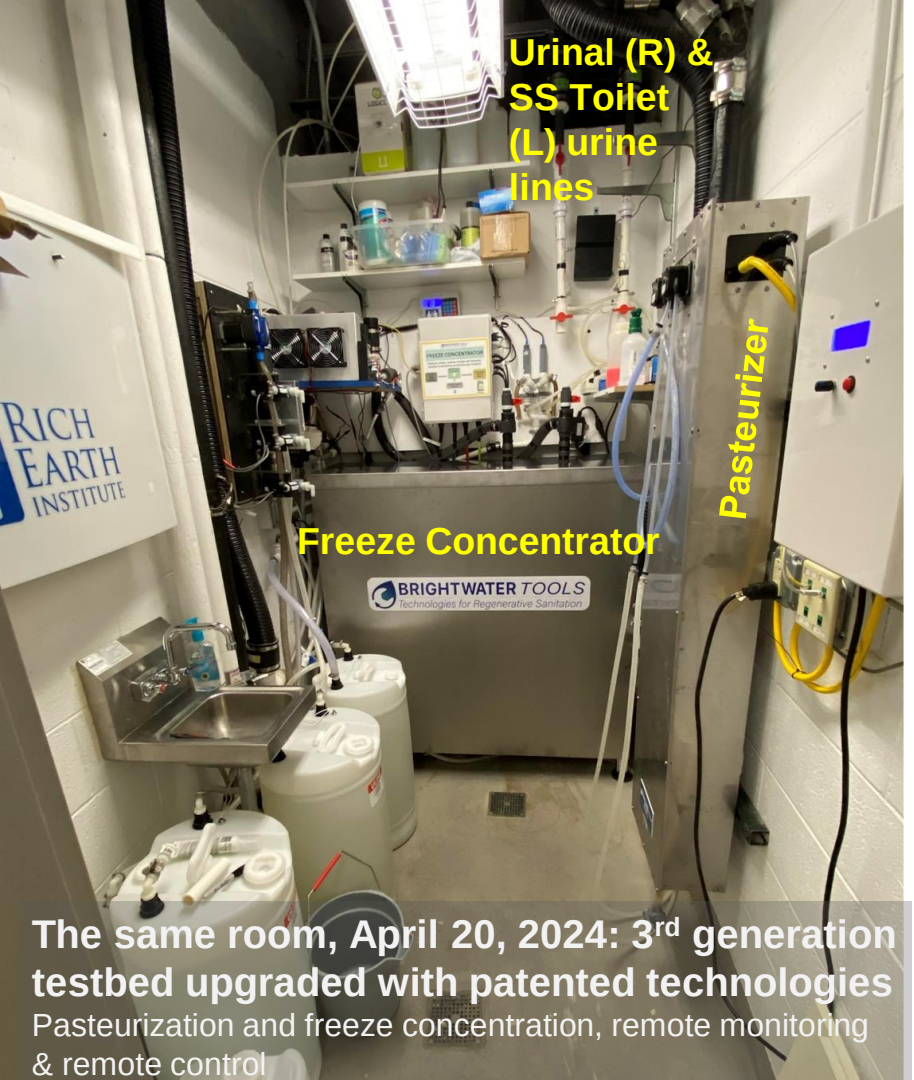

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Pasteurization and freeze concentration, remote monitoring & remote control

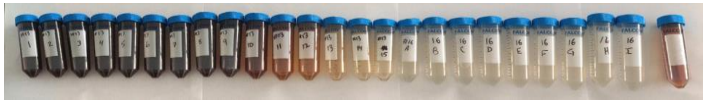
Extended batch processing equipment for P removal as struvite, K removal as K-struvite, and GAC sorption of trace contaminants.

There are three main goals to achieve with processing

Concentration

Elevating NPK levels to meet horticulture, turf, and food fertilizer needs

Freeze concentration
Distillation
Precipitation
Ion Exchange



Contaminants

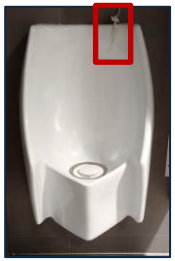
Removing chemical and biological contaminants to reduce risks

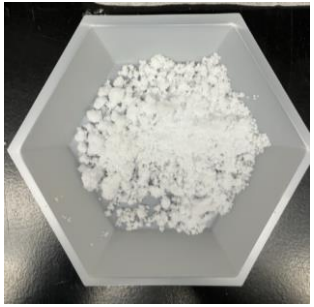
Pasteurization
Adsorption
pH
Advanced oxidation

Aesthetics

Making collection, processing, and final product use unobjectionable

Acidification or Basification
Process automation
Sealed tankage
subsurface application





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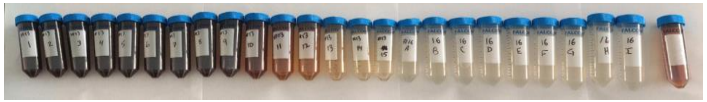

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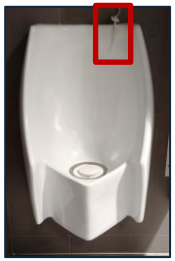
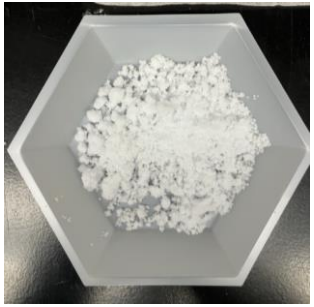




Sponsored research has supported advancing all aspects of urine recycling since 2015

https://youtu.be/iX1F4dYLF84

LCA & TEA

Value Chain Analysis

Training & Networks

Urine Collection, Plumbing & Transport

Processing

Product Use

Risk Analysis

Regs, Codes, & Standards

Perceptions

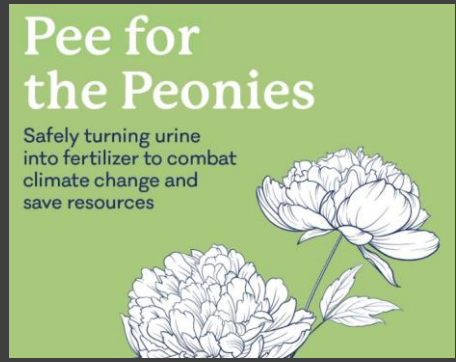
Field Trials:

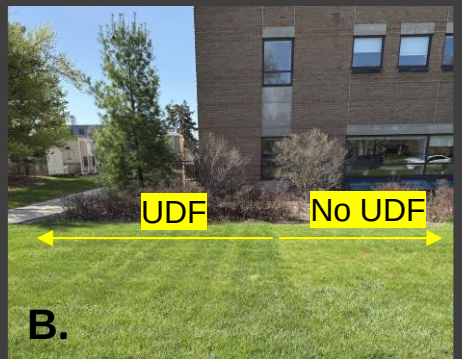
A. Regenerative Farm Study, 2025

B. Turf trial for campus grounds to replace early season fertilizer

C. Vermont carrot and lettuce trials 2015, 2016, 2018

D. Pee for the Peonies, 2018 - current





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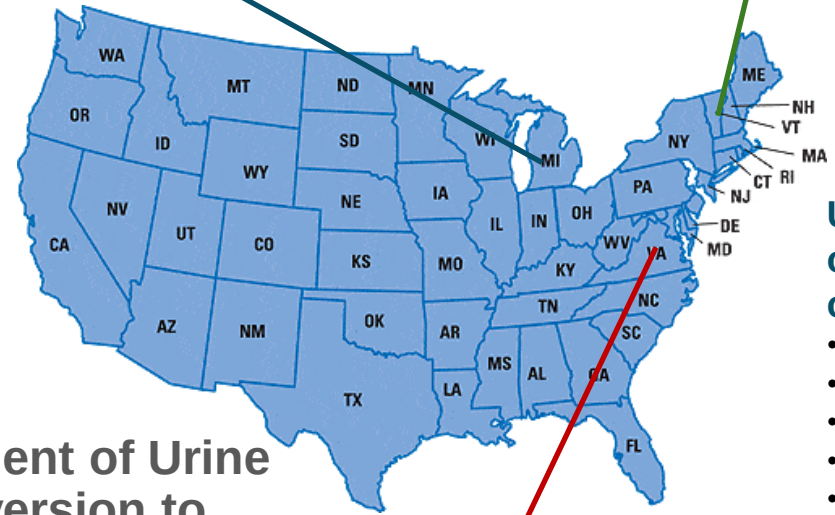
Perceptions

MICHIGAN (state-wide average & range)
32,000 – 3,500,000 m^3/day (150,000 population)
Variable NH_4^+ & TN limits, P limit = 0.7 ppm
Nitrification, A^2O process

VERMONT (small urban community in rural state)
85,000 m^3/day (25,000 population)
No TN limits, P limit = 0.2 ppm
Conventional Activated Sludge



Urine separation had lower overall environmental impact in 4 of 5 categories evaluated:

- Global Warming Potential
- Cumulative Energy Demand
- Freshwater Use
- Eutrophication
- ***Acidification Potential***

Life Cycle Assessment of Urine Diversion and Conversion to Fertilizer Products at the City Scale

Environmental Science & Technology
Environ. Sci. Technol. 2021, 55, 593–603

VIRGINIA (densely populated urban)
205,000 m^3/day (350,000 population)
Stringent TN (4 ppm) and P (0.18 ppm) limits
Advanced secondary, 5-stage Bardenpho

Hilton, Keoleian, Daigger, Zhou, Love. 2020. Life Cycle Assessment of Urine Diversion and Conversion to Fertilizer Products at the City Scale. ES&T. 55:593-603.

Sponsored research has supported advancing all aspects of urine recycling since 2015

https://youtu.be/iX1F4dYLF84

LCA & TEA

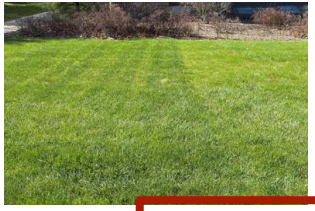
Value Chain Analysis

Training & Networks

Urine Collection, Plumbing & Transport

Processing

Product Use



Risk Analysis

Regs, Codes, & Standards

Perceptions

Exposure and Risk:

- We have assessed biological & chemical fate quite thoroughly for bacteria, viruses, pharmaceuticals, and PFAS.
- We completed an analysis that shows pharmaceutical exposure via UDF is ≤ current exposures via irrigation water applied to crops.

Perceptions:

- We increasingly understand what stakeholders have questions about and how to talk about them.
- Users come to acceptance rather quickly with basic information about urine recycling.
- We are learning effective points for different stakeholders.

WATER ENVIRONMENT & REUSE FOUNDATION WE&RF Final Report

ELEMENTA Science of the Anthropocene

Environmental Science & Technology

ACS ES&T Water

Analytical Methods

sustainability

American Society for Microbiology | Applied and Environmental Microbiology®

JAFSCD

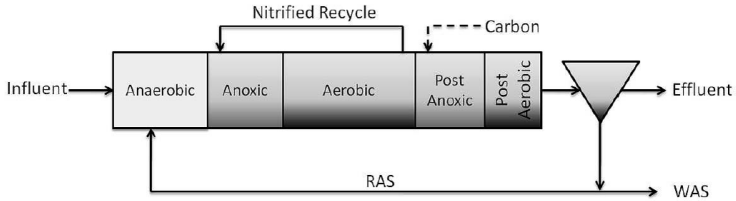
Journal of Agriculture, Food Systems, and Community Development
ISSN: 2152-0801 online
https://foodsystemsjournal.org

water ENVIRONMENT RESEARCH

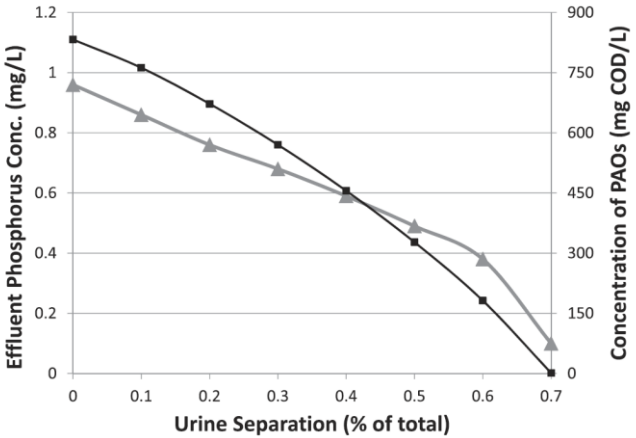
87(12), 2015

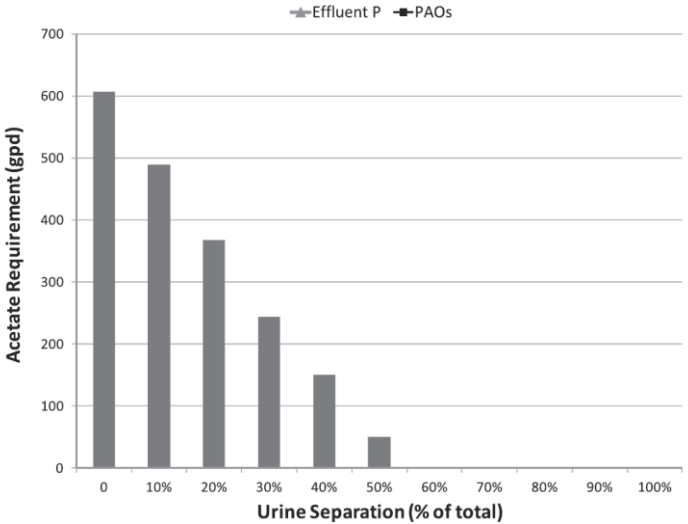
Source Separation of Urine as an Alternative Solution to Nutrient Management in Biological Nutrient Removal Treatment Plants

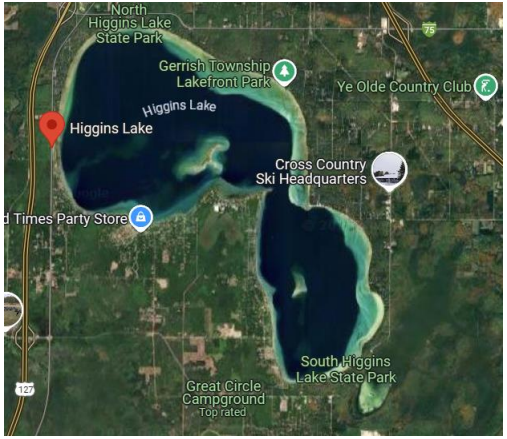
Jose Jimenez[1*], Charles Bott[2], Nancy Love[3], John Bratby[4]

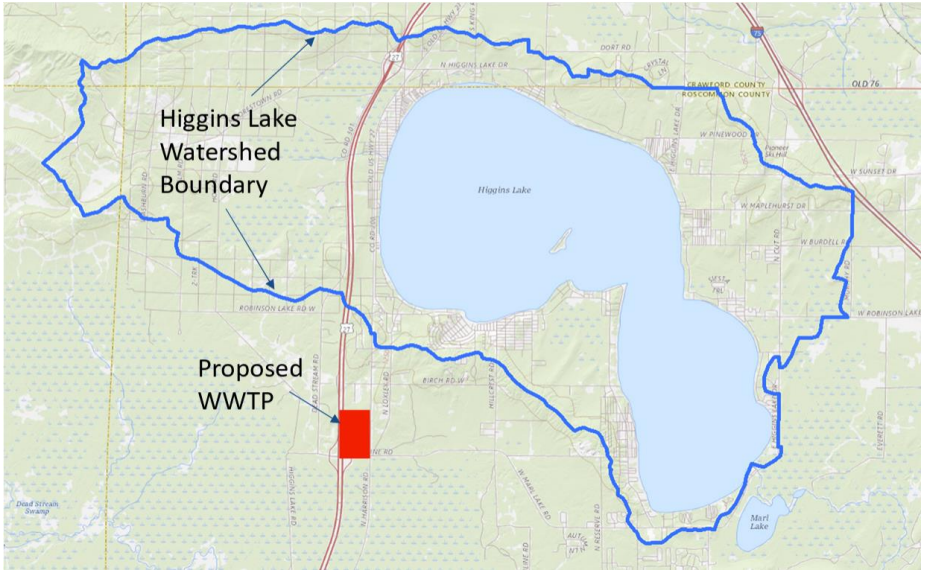


- Urine separation reduces effluent P – thereby reducing chemical demand for P removal
- For BNR plant, reduce external C need as TN requirements decrease
- Urine separation reduces aeration required for nitrification
- At high % urine separation, can reduce SRT and incorporate carbon-focused intensification technologies







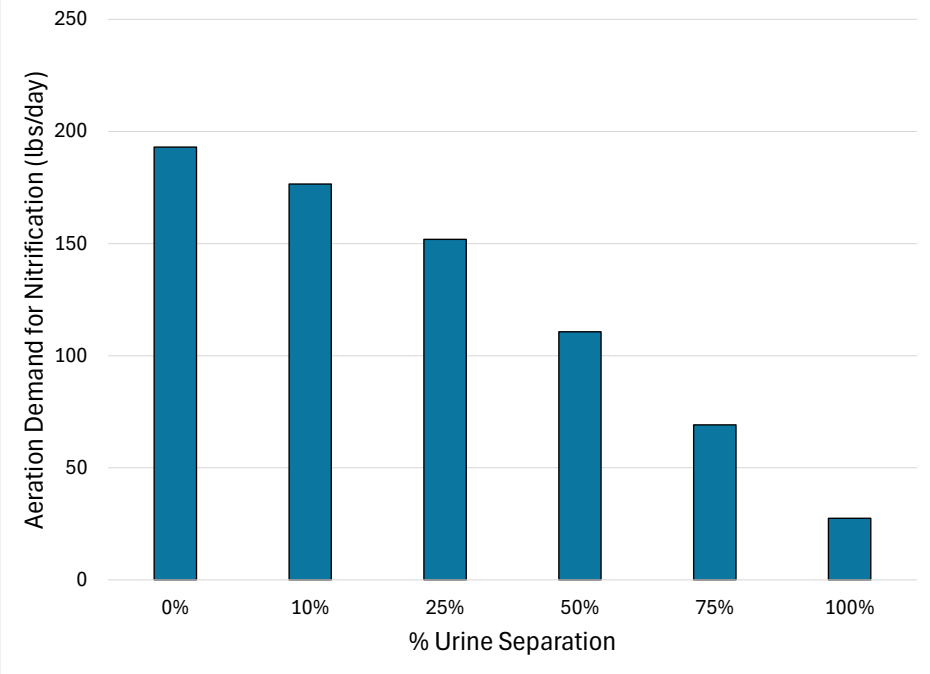


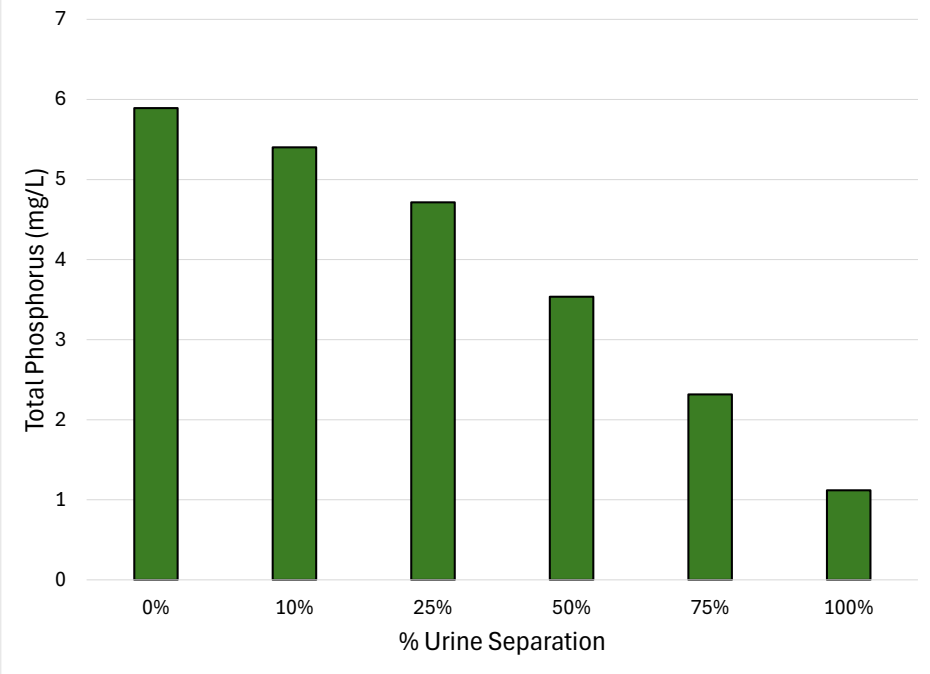
Pumped flow → Conventional AS treatment → Infiltration basins

Conventional AS treatment → Biosolids to landfill

FLEIS&VANDENBRINK
DESIGN. BUILD. OPERATE.

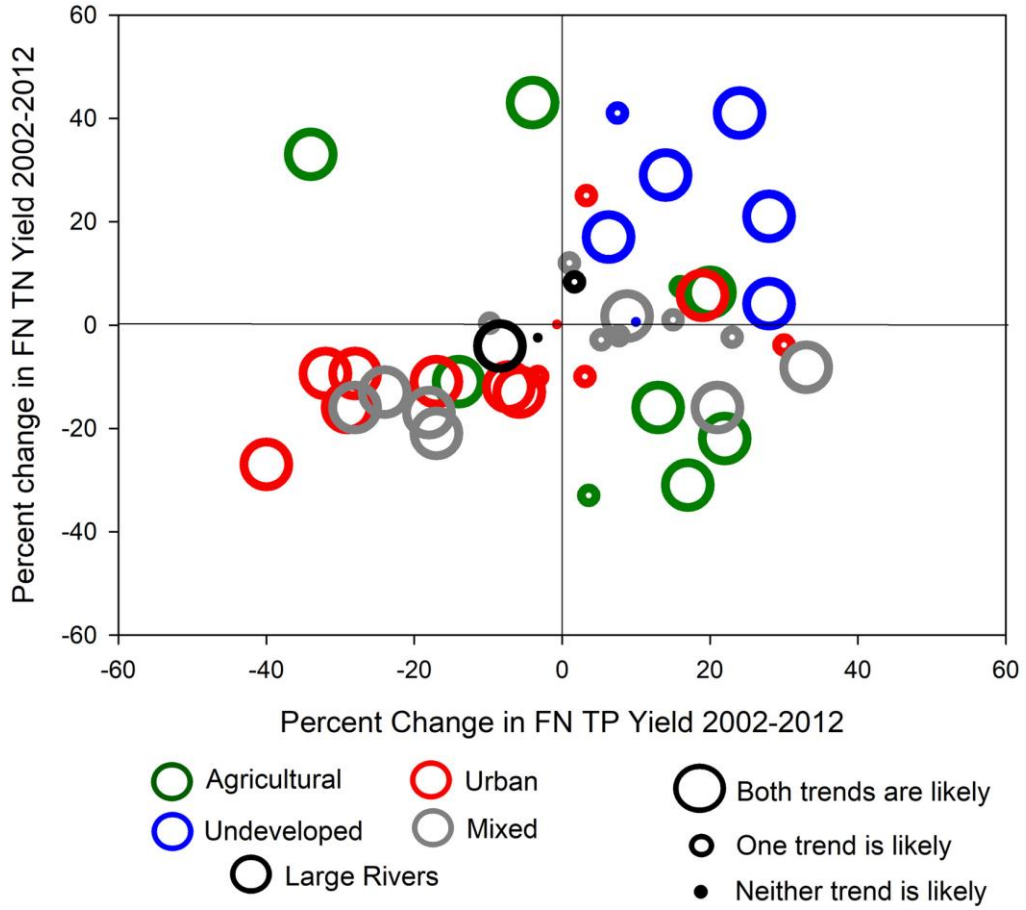
Can urine recycling can enhance treatment capacity and support process intensification for Higgins Lake?





Undeveloped, agricultural, and mixed development areas are trending to become the locations that are more vulnerable to nutrient imbalances

Are they locations for innovation advancement with urine separation?

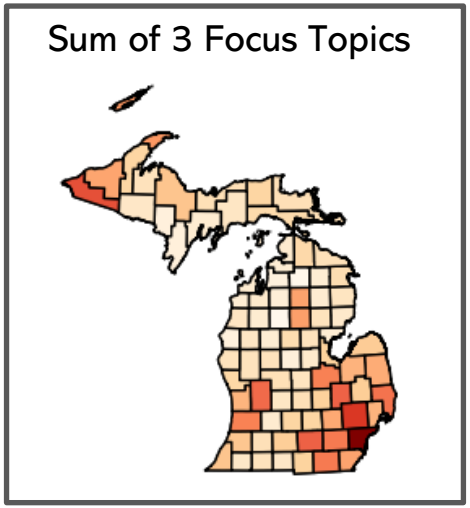


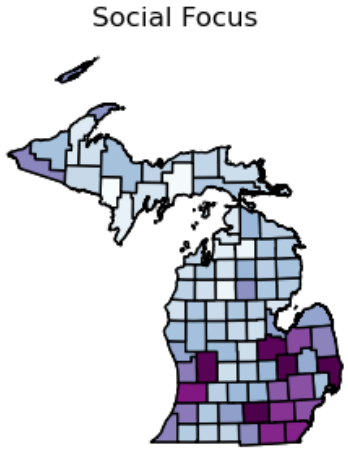
Oelsner, G. P. and E. G. Stets. 2019. Recent trends in nutrient and sediment loading to coastal areas of the conterminous U.S.: Insights and global context. Science of the Total Environment. https://doi.org/10.1016/j.scitotenv.2018.10.437

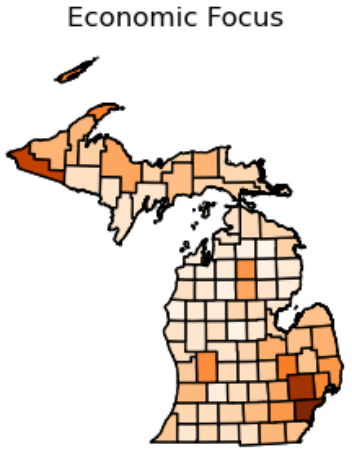
More favorable
for urine recycling

Less favorable
for urine recycling

UDF products may be best employed as regional fertilizer sources







Work by Joe Lybik

Collection at big events

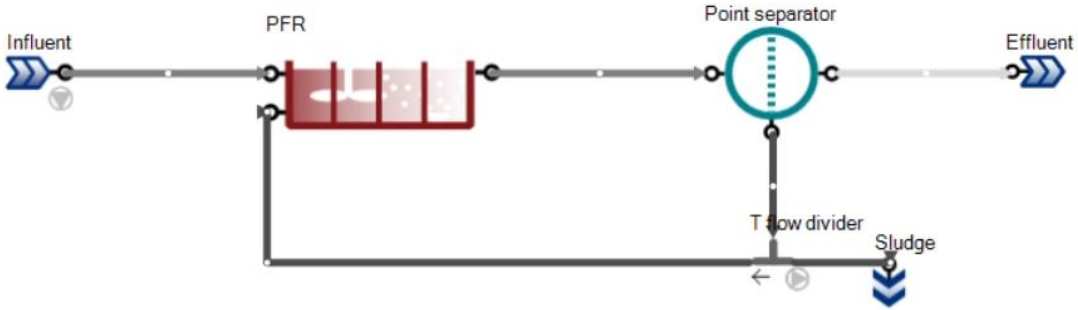
Collection at big events

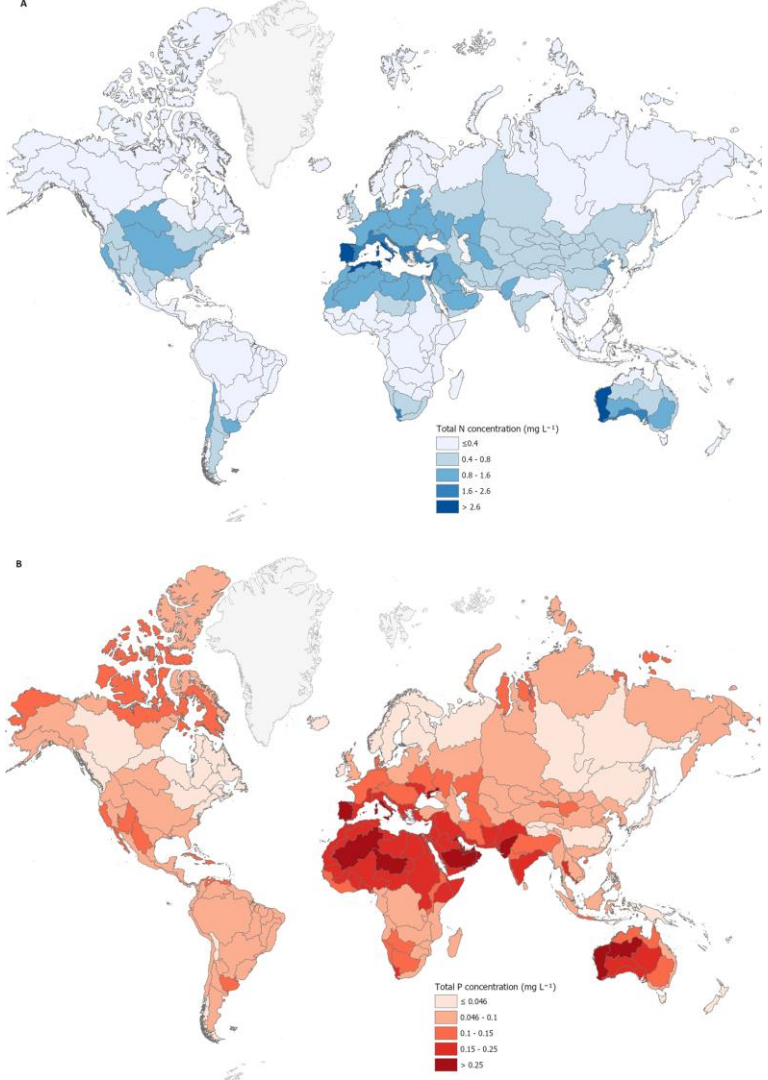
Each of us produces enough nitrogen in our daily pee to fertilize enough wheat to bake a loaf of bread.

Seems a shame to waste it!

RICH EARTH INSTITUTE

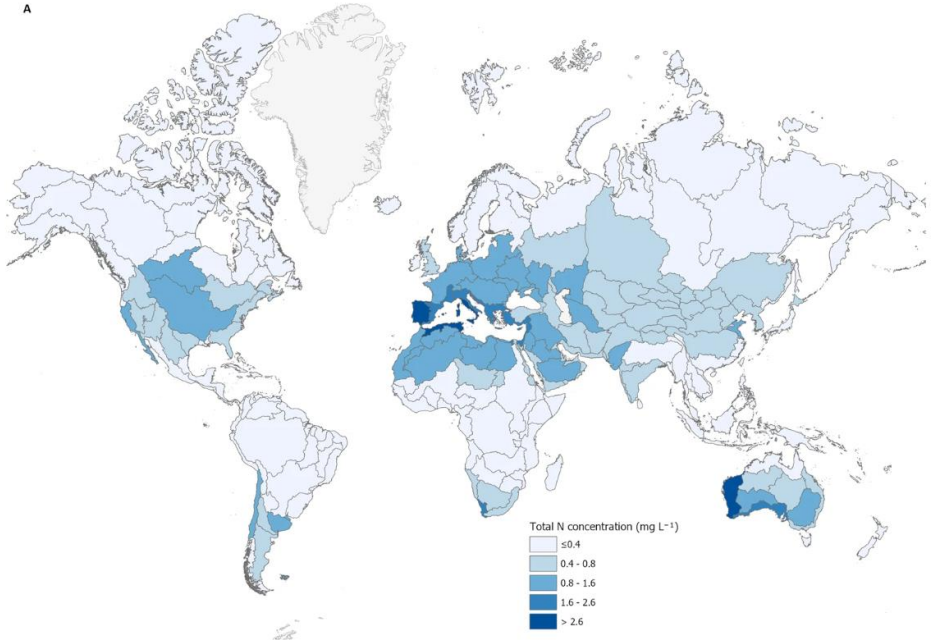
100,000 gpd
10 day SRT



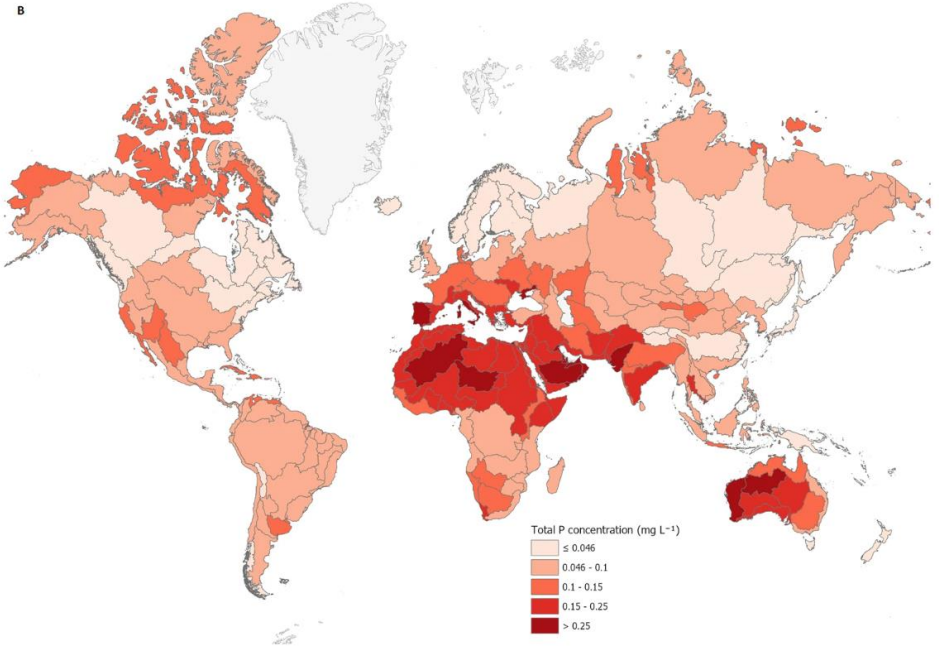

A
Total N concentration (mg L⁻¹)
≤0.4
0.4 - 0.8
0.8 - 1.6
1.6 - 2.6
> 2.6
B
Total P concentration (mg L⁻¹)
≤ 0.046
0.046 - 0.1
0.1 - 0.15
0.15 - 0.25
> 0.25

Global prediction of algal growth potential in freshwater systems based on river data

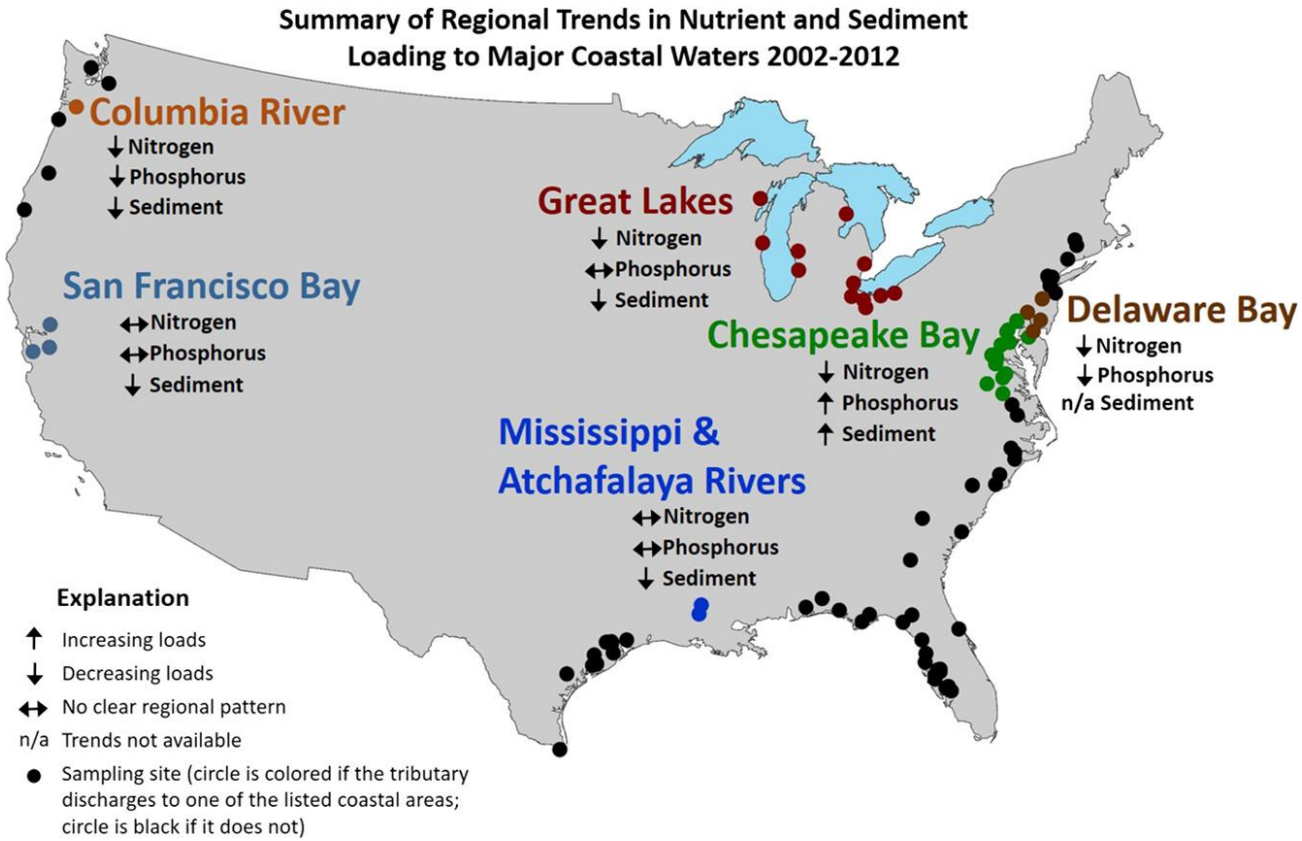
NITROGEN



PHOSPHORUS



McDowell, Noble, Pletnyakov, Haggard, and Mosley. 2020. Global mapping of freshwater nutrient enrichment and periphyton growth potential. Scientific Reports. 10:3568.



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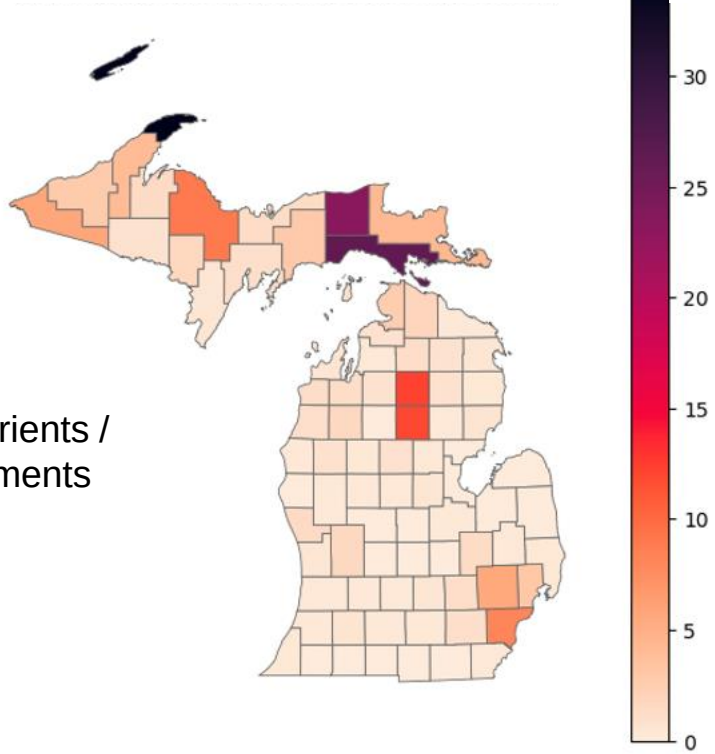
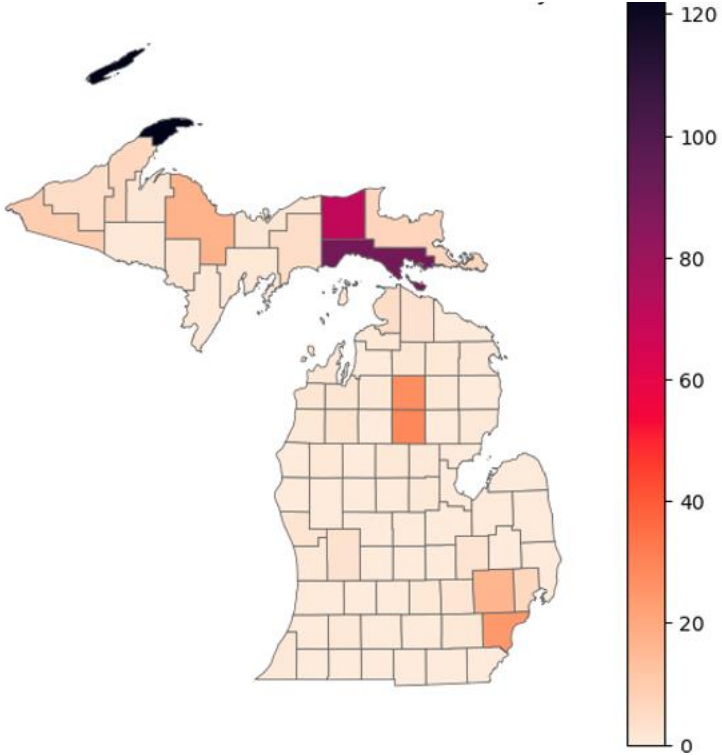
Nitrogen fertilizer offsets via centralized wastewater recovery



Phosphorus fertilizer offsets via centralized wastewater recovery



Fertilizer offset =
Recoverable Nutrients /
Fertilizer requirements

Values higher than 1 indicate that a county can offset all of their fertilizer requirements through recovering nutrients from centralized treatment plants within the county. **Note this analysis does NOT consider onsite treatment systems**

By Joseph Lybik, Univ Michigan