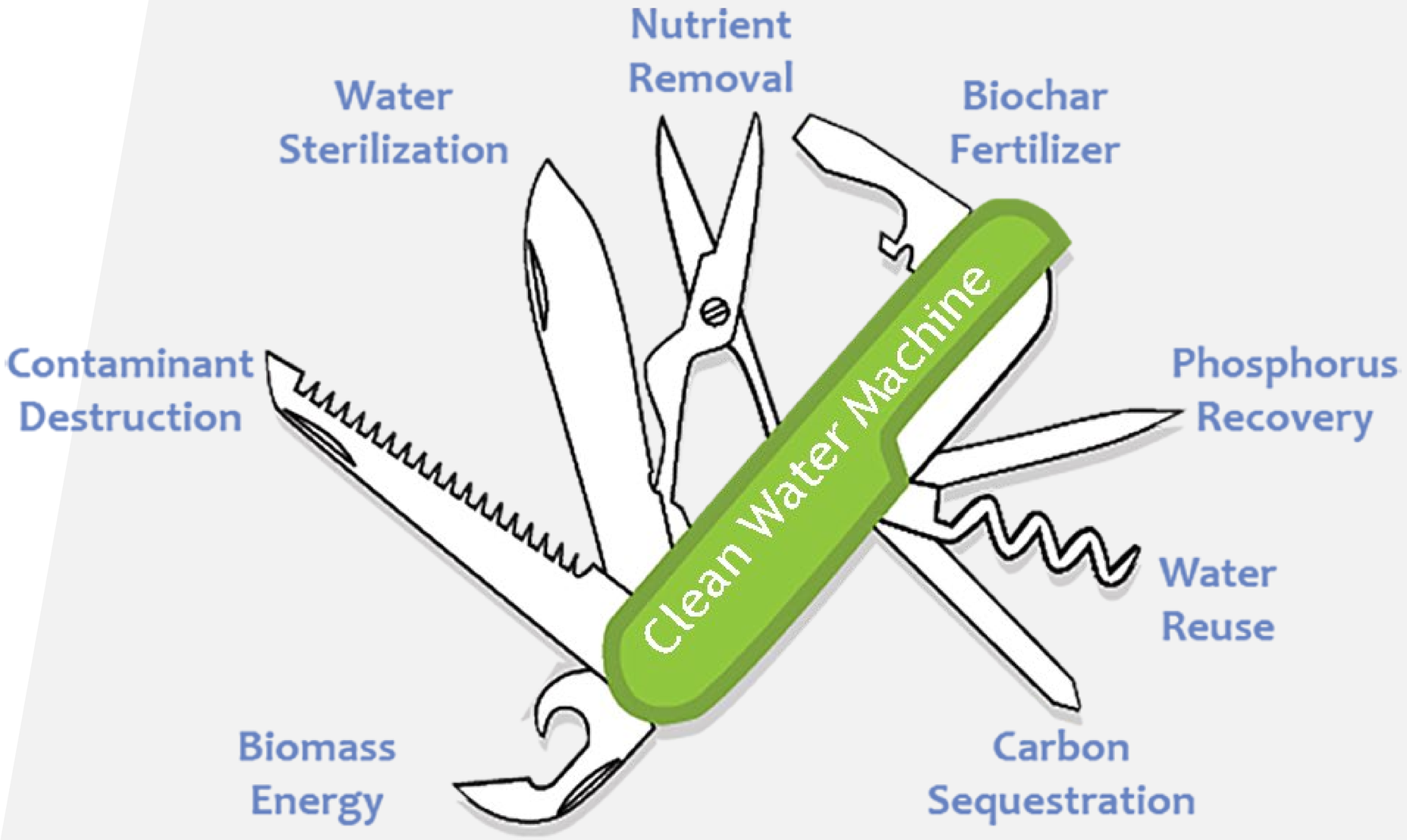
University of Idaho

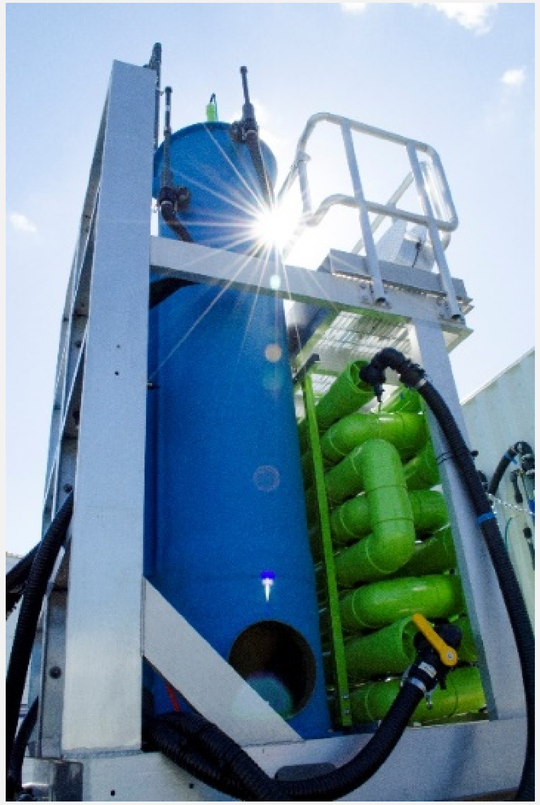
# CLEAN WATER MACHINE CHANNELBOX REACTIVE FILTRATION

## A NATURE MIMICRY APPROACH TO DISTRIBUTED SURFACE WATER TREATMENT FOR ULTRALOW P AND HG


Nutrient Removal
Water Sterilization
Biochar Fertilizer
Contaminant Destruction
Clean Water Machine
Phosphorus Recovery
Water Reuse
Biomass Energy
Carbon Sequestration

# CLEAN WATER MACHINE

## FOURTH GENERATION REACTIVE FILTRATION

# REACTIVE FILTRATION (RF)

Physical filtration combined with reactive chemistry (or microbiology) to modify water contaminants, including pathogens, and remove or destroy them from water.

Shirebrook UK

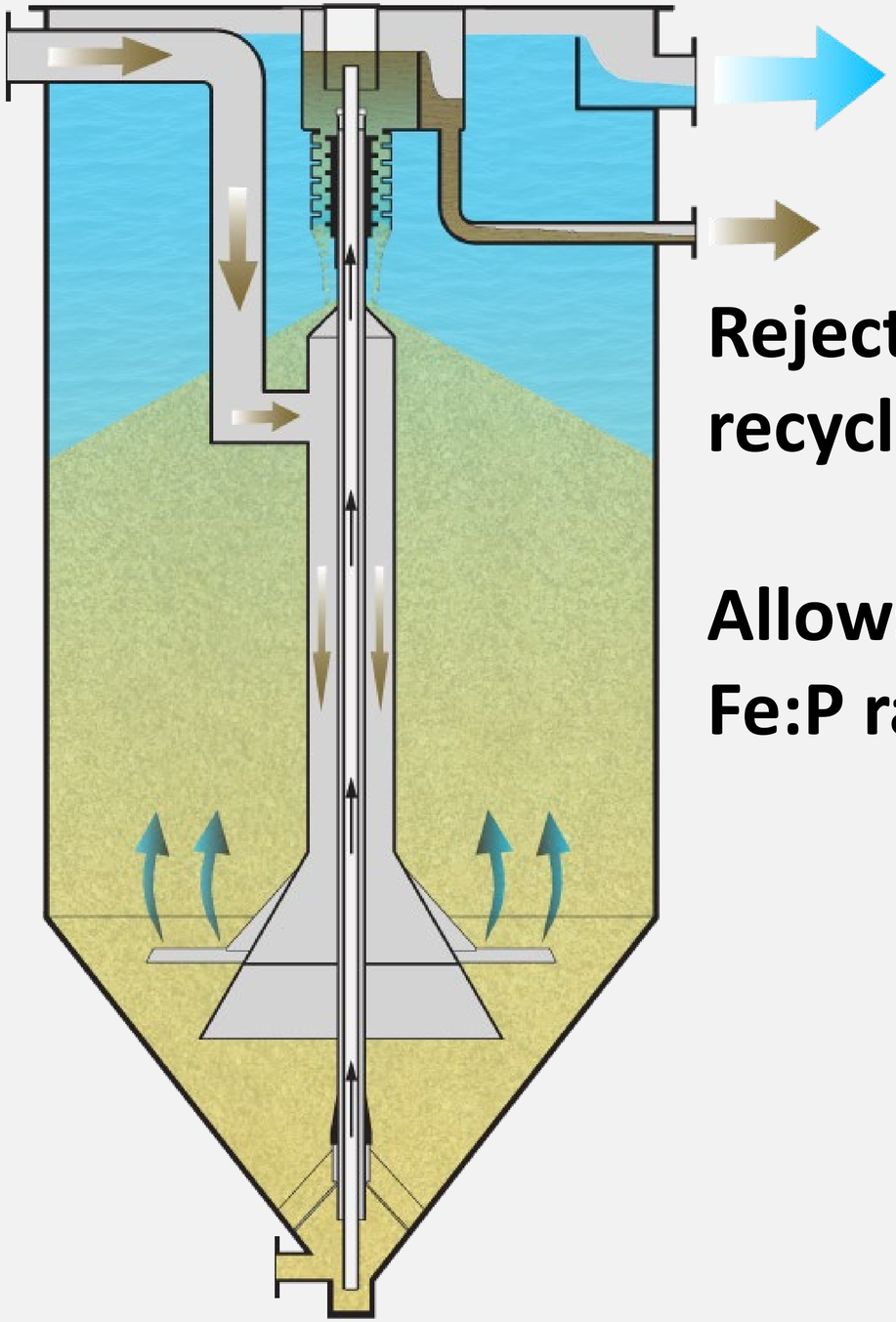
# CHANNELBOX™

- Waterproof Part-Submersible Shipping Containers
- High-Flow Water Treatment
  - 40 Foot Container = 1 MGD
- Motive Force of the Water Drives Process
- Kalman Filter/AI Controls
  - Sensor data: linear quadratic estimation

# REACTIVE FILTRATION

## FIRST GENERATION RF

Upflow
Continuous
Backwash
Moving Bed Sand
Filter

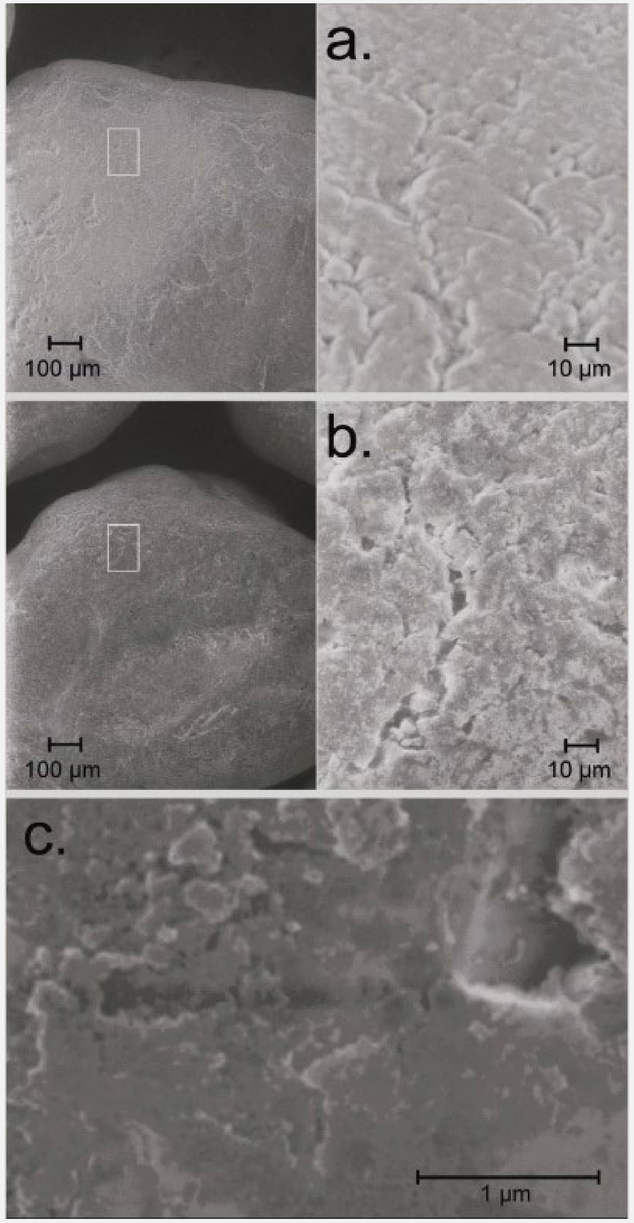


# RF-SACRIFICIAL ADSORPTIVE CATALYST

**Hydrous Ferric Oxide (HFO) Coated Sand**

| | |
|---|---|
| **$Fe^{3+}$** | Blue PRO |
| **$Fe^{3+/2+}$ + Ozone** | Blue CAT |
| **Biochar** | N-E-W Tech |
| **Various** | ChannelBox™ |
| **“Other” Separation Tech** | BlueWave™ |

Scanning Electron Micrographs

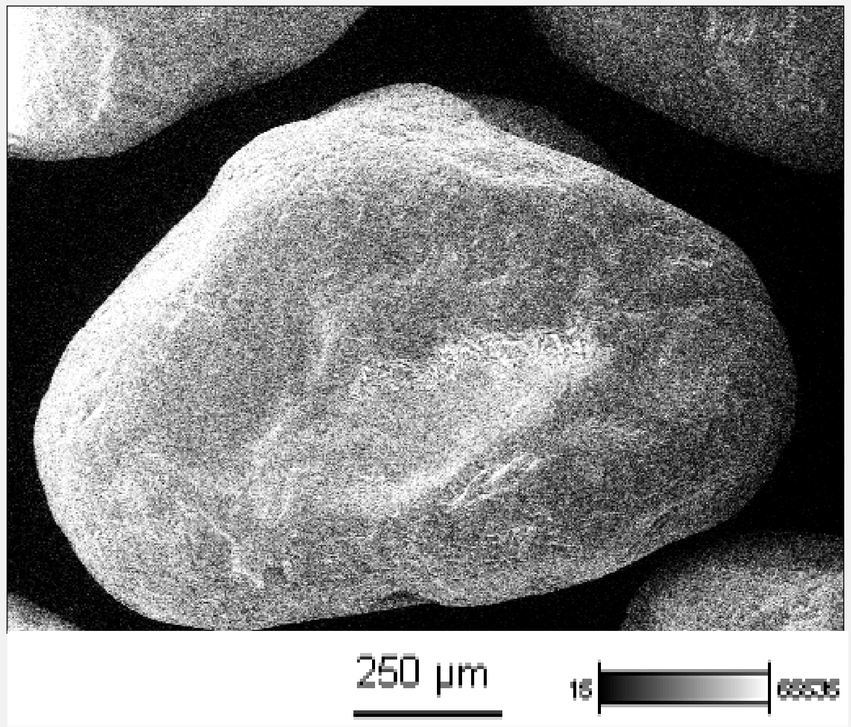


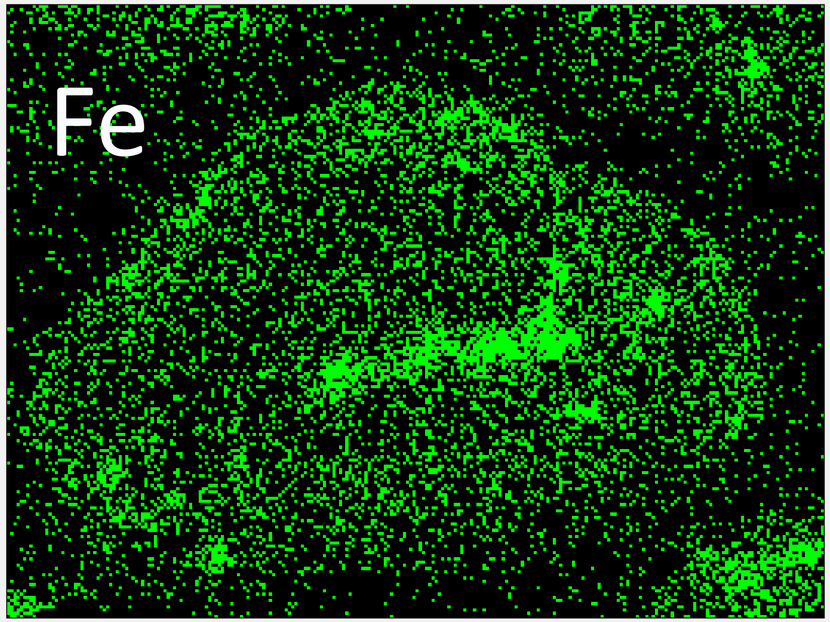

# RF-ADSORPTION BY HFO

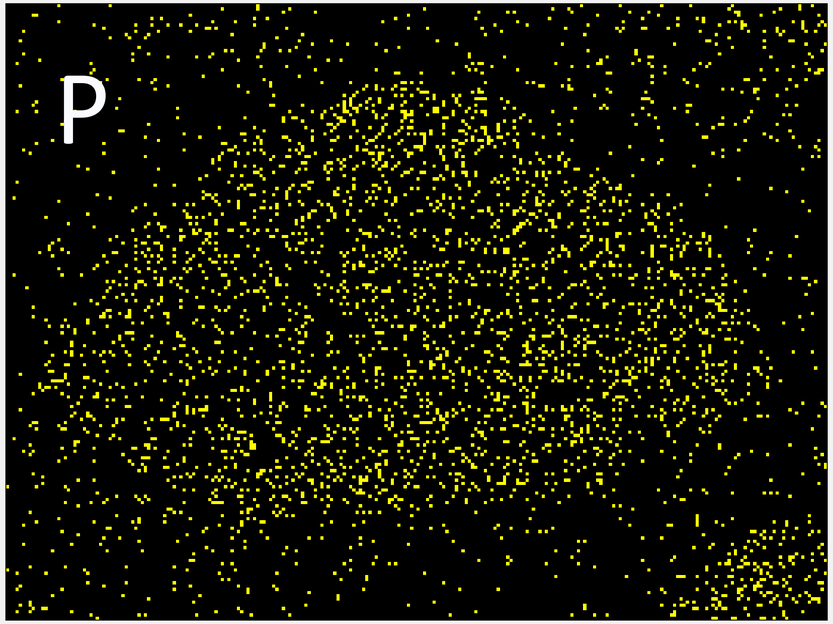
## HYDROUS FERRIC OXIDE

Sand surface with HFO-coating

Contaminants coordinate w/ HFO



# CITRONELLE, ALABAMA

Currently the lowest TP discharge permit in the US: at **0.022 mg/L**

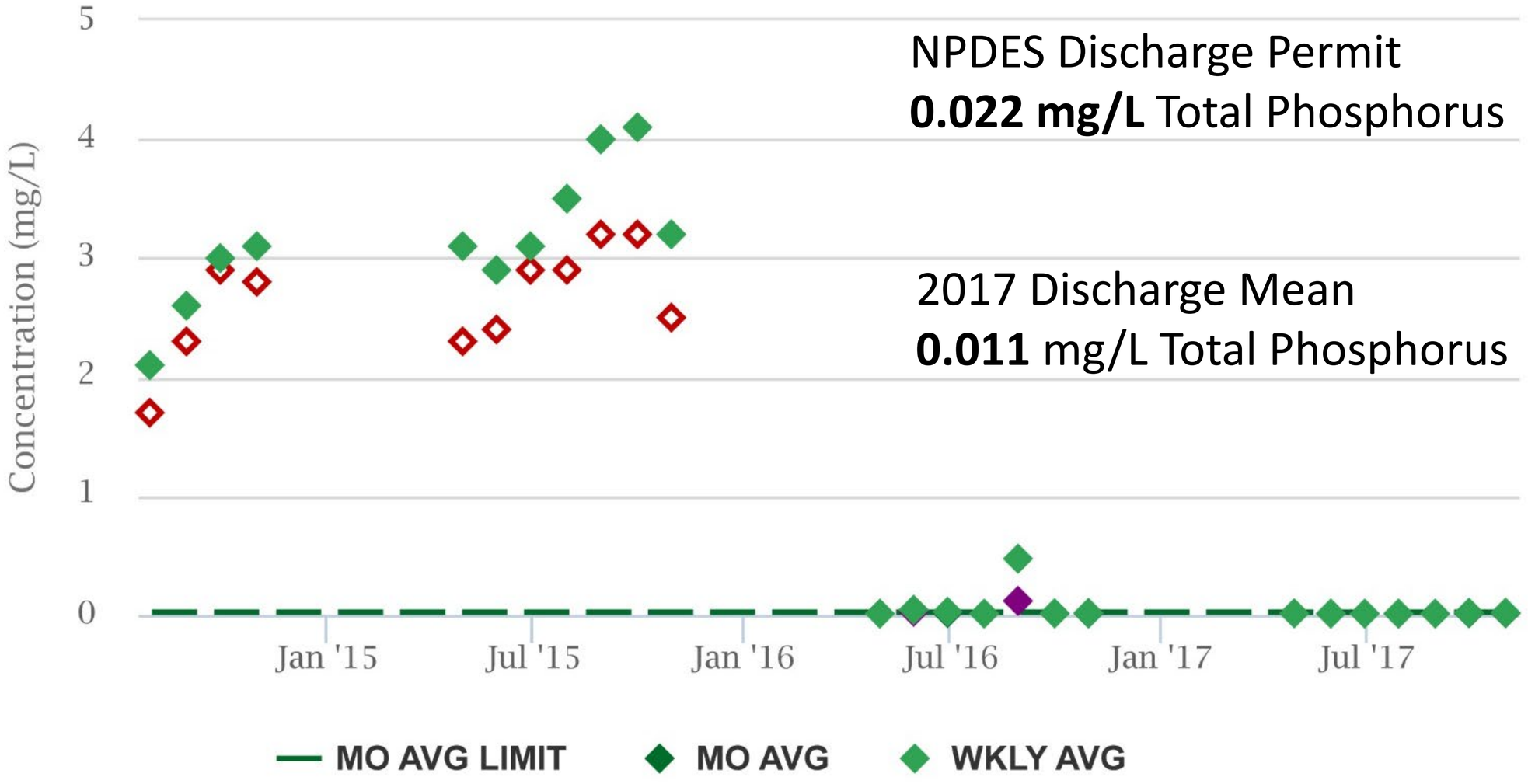
Commissioned in March ‘16 at **<0.010 mg/L**

US NPDES report mean 2017 at **0.011 mg/L**

CITRONELLE WASTEWATER TREATMENT PLANT (AL0060887) 001 - Phosphorus, total [as P] - Effluent Gross - Concentration

Late/Missing Reports Timeline

# USEPA ECHO DATABASE




NPDES Discharge Permit
**0.022 mg/L** Total Phosphorus

2017 Discharge Mean
**0.011** mg/L Total Phosphorus

# CITRONELLE, AL WWTF

99.7%

TP Removal

from 3.5 to 0.011 mg/L

Oligotrophic Nutrient Level

# MERCURY + P REMOVAL INTERNATIONAL FALLS, MN


RESEARCH ARTICLE

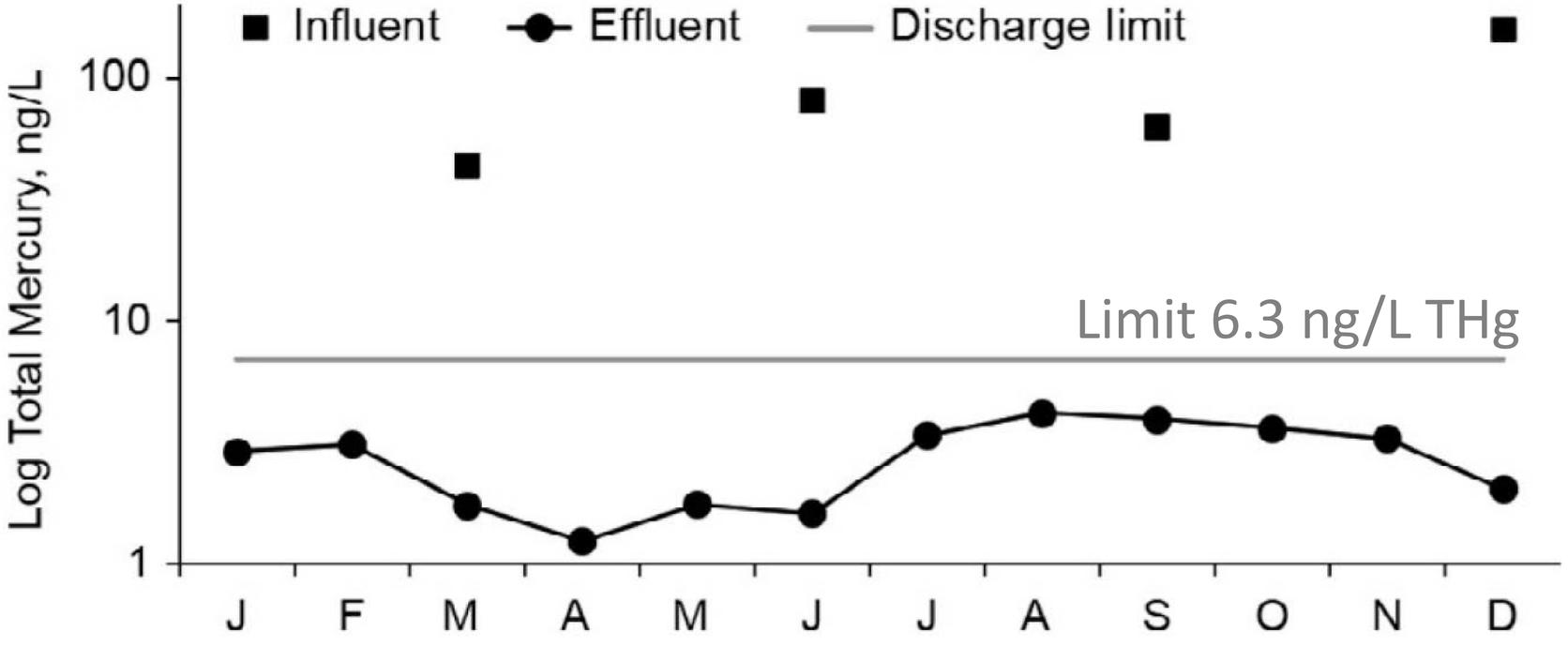
Water Environment Federation
the water quality people

**Mercury removal from municipal secondary effluent with hydrous ferric oxide reactive filtration**

Marc W. Beutel,[1] Stephen R. Dent,[2,3] Remy L. Newcombe,[4] Gregory Möller[5*]

**3 MGD**
**TP and THg Removal**

87 — 2.7 ng/L THg
97% THg Removal



# HG REMOVALS

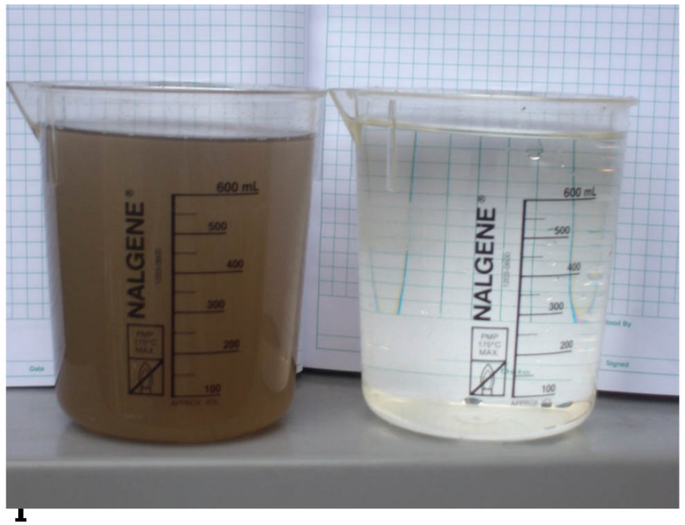
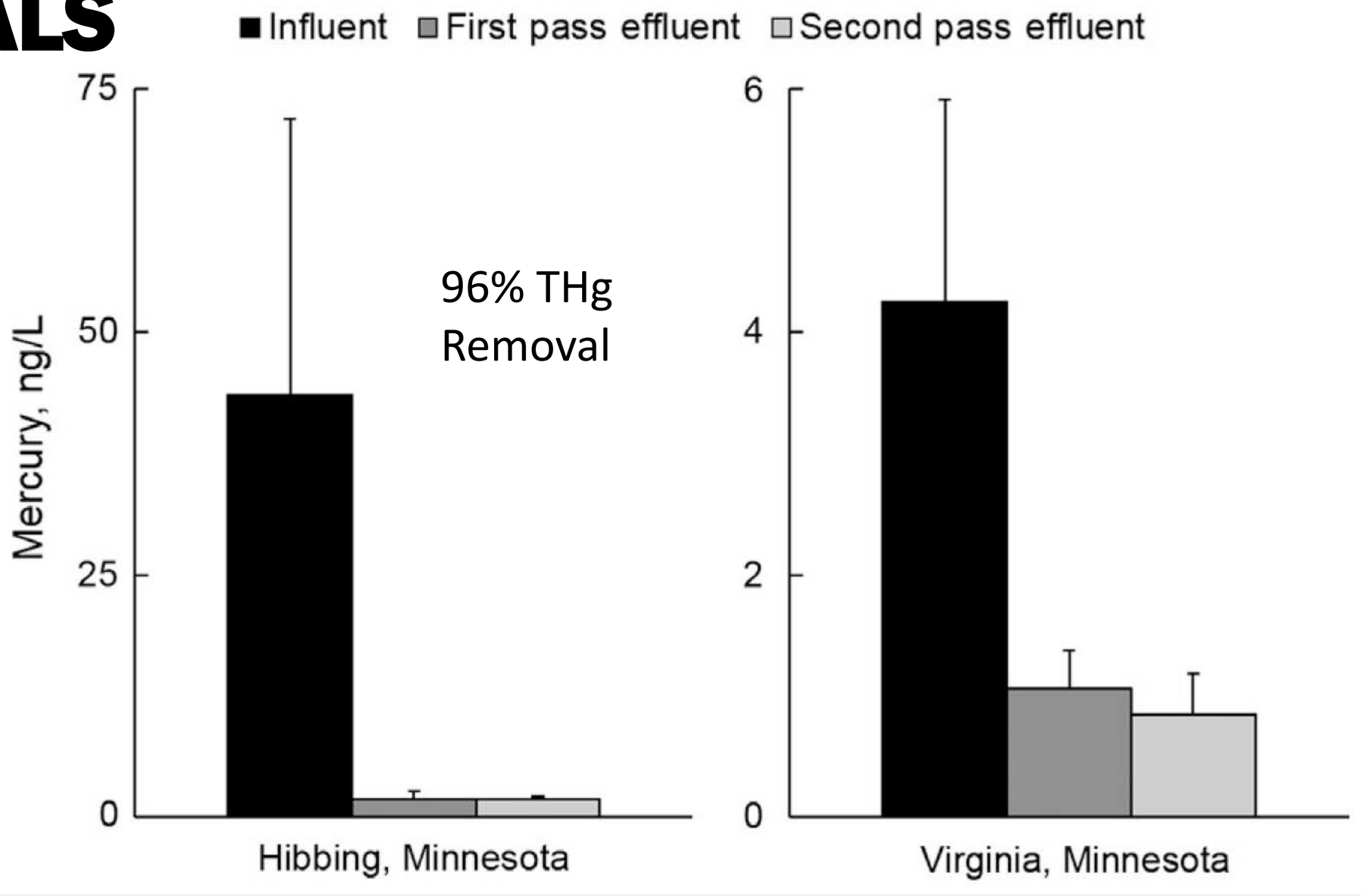



**FIGURE 3**: Blue PRO® pilot influent and final effluent grab samples during the Hibbing pilot.

Hibbing, Mn
46.9 to 0.3 NTU
43.6— 1.8 ng/L THg



# IRON OZONE CATALYSIS
# WHAT US$100 BUYS YOU

Treitler, 2010

**Rh** (0.5 g)

**Pd** (6.4 g)

**Pt** (2.0 g)

**Au** (2.6 g)

**Ni** (5,300 g)

**Cu** (15,000 g)

**Fe** (500,000 g)

Horwich UK



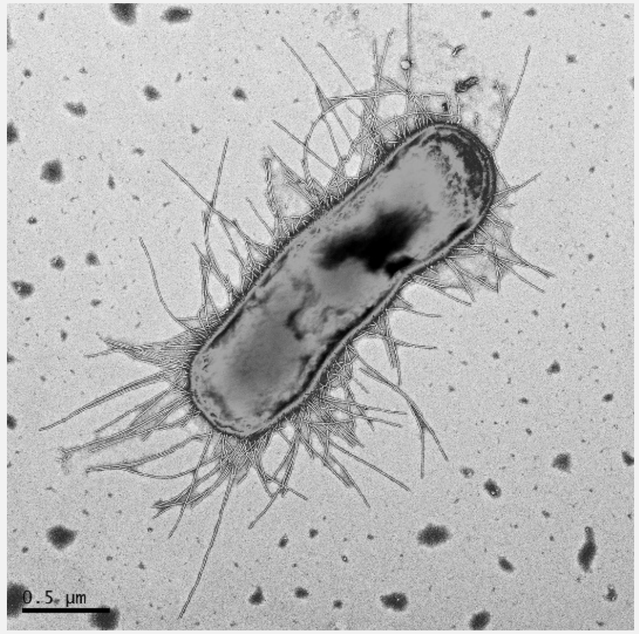
2016 – 2018
UK TRIALS

# REACTIVE FILTRATION CATALYTIC OXIDATION

**$Fe^{3+/2+}$ + Ozone**

Remove Nutrients
Destroy Pathogens
Destroy Organic Chemicals

# CATALYTIC OXIDATION STERILIZATION E. COLI




| **Escherichia coli, E. coli (MPN/100mL)** | *Lab Reporting Maximum Level | | | | # Lab Reporting Minimum Method Detection Level | | | |
|---|---|---|---|---|---|---|---|---|
| | **Influent** | | | **Mean** | **Effluent** | | | **Mean** |
| Trial 1 | 35000 | 35000 | 54000 | **41333** | 1.8# | 1.8# | 1.8# | **1.8#** |
| Trial 2 | 1600* | 1600* | 1600* | **1600*** | 1.8# | 1.8# | 1.8# | **1.8#** |
| Trial 3 | 1600* | 1600* | 1600* | **1600*** | 1.8# | 1.8# | 1.8# | **1.8#** |

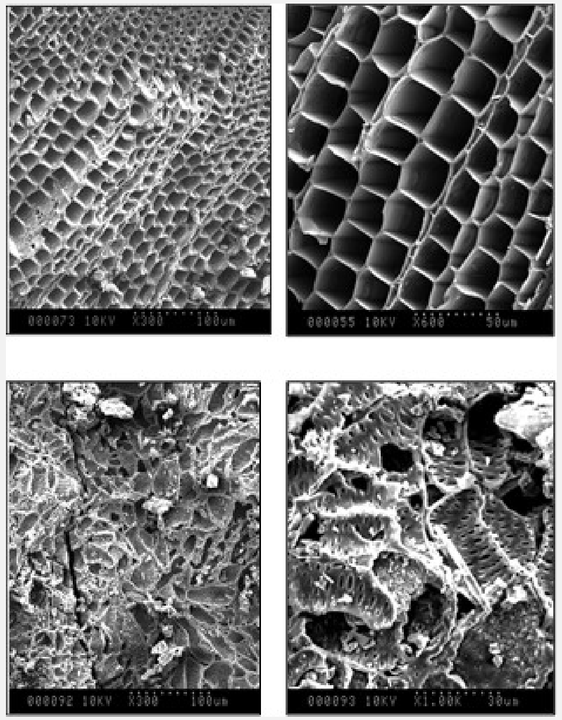
MPN=most probable number

# CATALYTIC OXIDATION
# CEC DESTRUCTIVE REMOVAL

Compounds of Emerging Concern, Micropollutants, Priority Substances

**ng/L**

| $Fe(II) + O_3$ | Influent | Effluent | MDL | % Removal |
|---|---|---|---|---|
| Bisphenol A | 53 | ND | 4 | 96.2% |
| Caffeine | 45 | 1.9 | 1 | 95.8% |
| Carbamazepine | 360 | ND | 0.4 | 99.9% |
| DEET | 56 | ND | 0.7 | 99.4% |
| Dilantin | 66 | ND | 0.2 | 99.8% |
| Diclofenac | 80 | ND | 0.9 | 99.4% |
| Fluoxetine | 43 | 1.8 | 0.8 | 95.8% |
| Gemfibrozil | 210 | ND | 0.5 | 99.9% |
| Hydrocodone | 56 | ND | 0.5 | 99.6% |



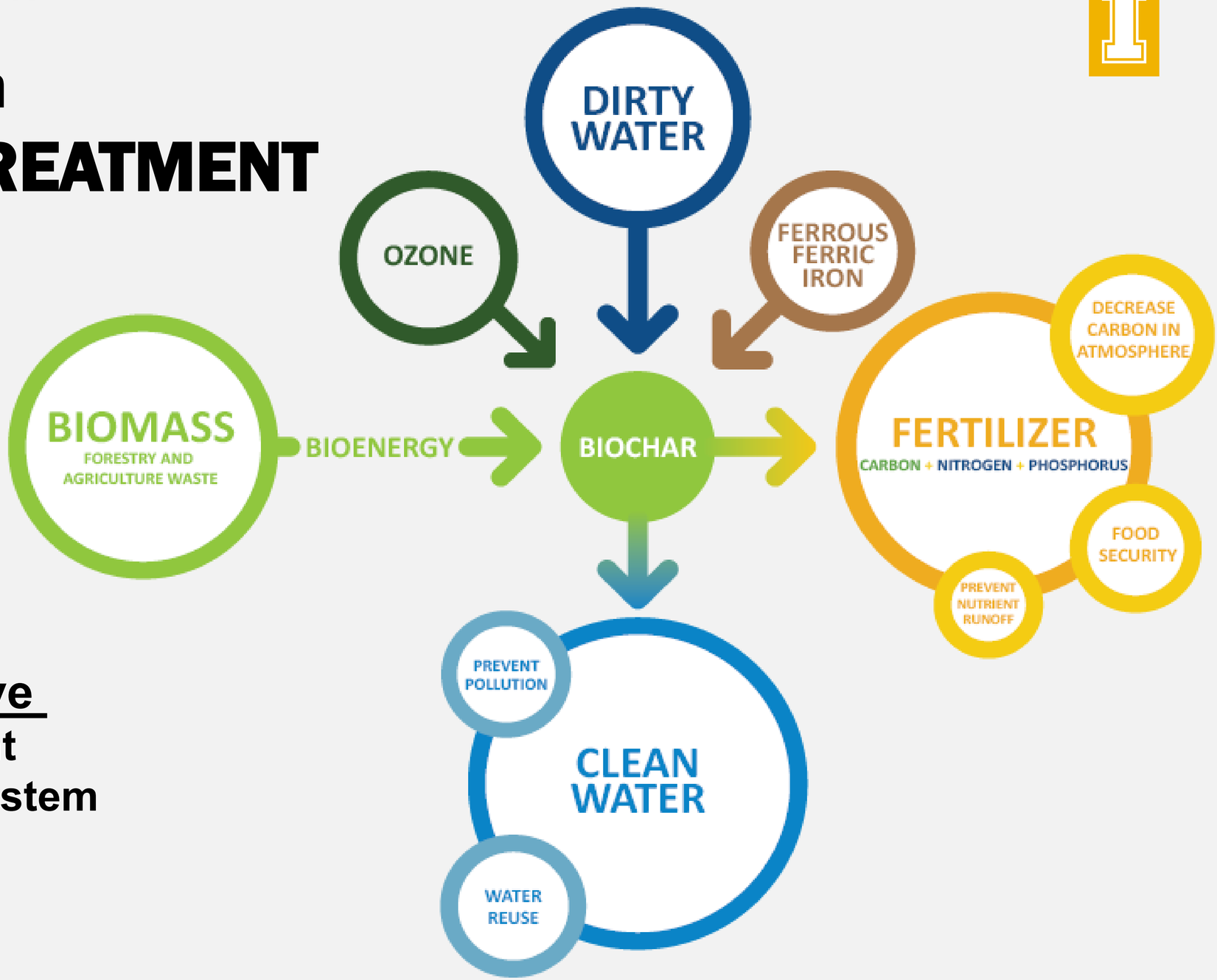
# BIOCHAR BIOCARBON

Nutrient-Energy-Water

# N-E-W Tech

# BIOCHAR WATER TREATMENT

## N/P Recovery

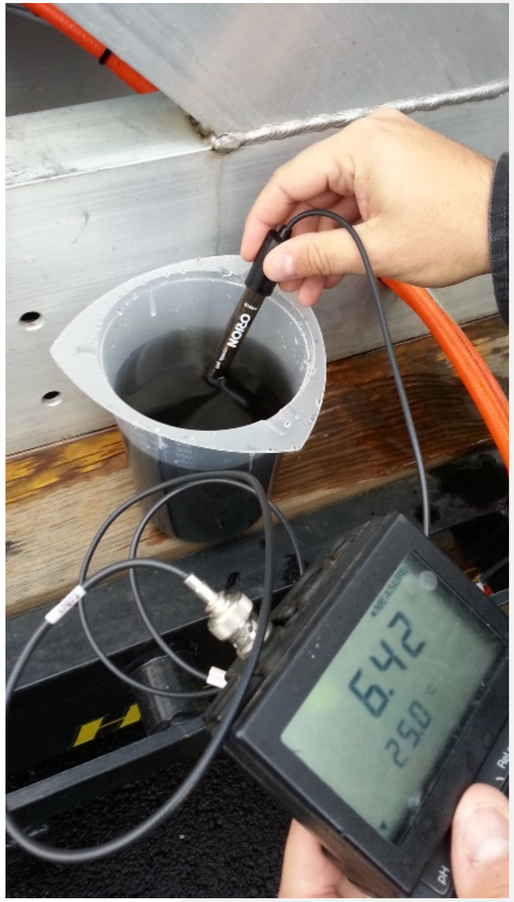



**Carbon Negative**

Water Treatment

Soil Amendment System

# BIOCHAR WATER TREATMENT




**Phosphorus: 1.7% w/w (13X upcycle)**

**Nitrogen: 0.8% w/w (3X upcycle)**