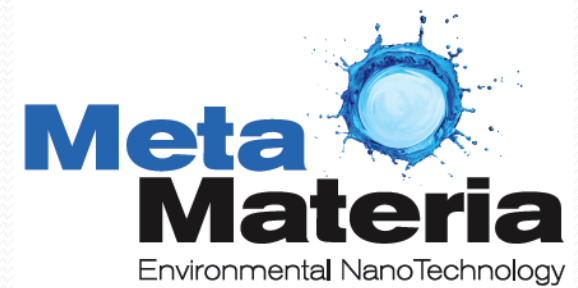


Phosphorus Management



Water Clean Up



PO4 Sponge

Removes Soluble Phosphorus

Dissolved Reactive Phosphorus (DRP)



BIO Lair

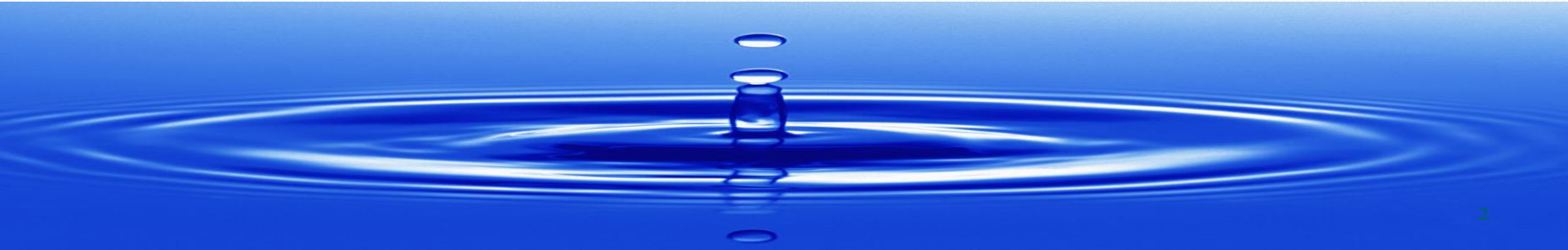
Bacteria Multiplier

for Fast Bioremediation

to remove organics & nitrogen



MetaMateria • 870 Kaderly • Columbus, OH 43228 • metamateria.com

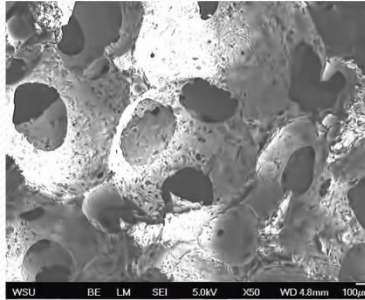


Nano-Enhanced Media

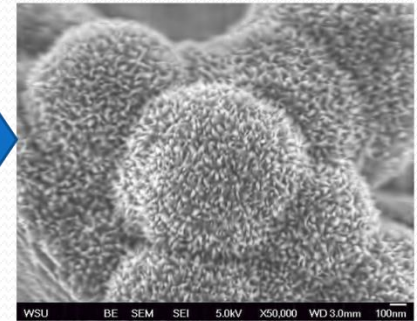
Nano Provides

- >120 m²/gram Surface
- More Active Capture Sites
- Catalyze Reactions
- Regeneration – Multiple Use

Porous Media



Nano-Enhanced



Used For:

- Phosphorus Removal
 - *Holds more phosphorus/Kg of media*
- Metal Ion Removal
 - *Arsenic, Lead, Selenium, Copper, Nickel, etc.*
- Remove trace organics, pharmaceuticals, pathogens, insecticides

Market Drivers

Water is a Critical & Often Scarce Resource

- Recycled water becoming more important
- New approaches needed to remove contaminants
 - Better Performance & Lower Cost needed

Decisions Driven by

- Economic Attractiveness (make or save money)
- Environmental Regulations (meet requirements)

Phosphorus Sources Needed

- Source of Phosphorus being used up (Phosphate Rock)
- Demand increasing (fertilizer, food/water additive)

Phosphorus Situation

- **Phosphorous Accumulates**

Leads to increases in toxic algae

- water quality & health issues
- eutrophication
- comes from food, fertilizer, etc.
- limited sources

- **Phosphorous** in water needs to be lowered

- **Removal methods**

Chemical methods – creates acids that harm environment

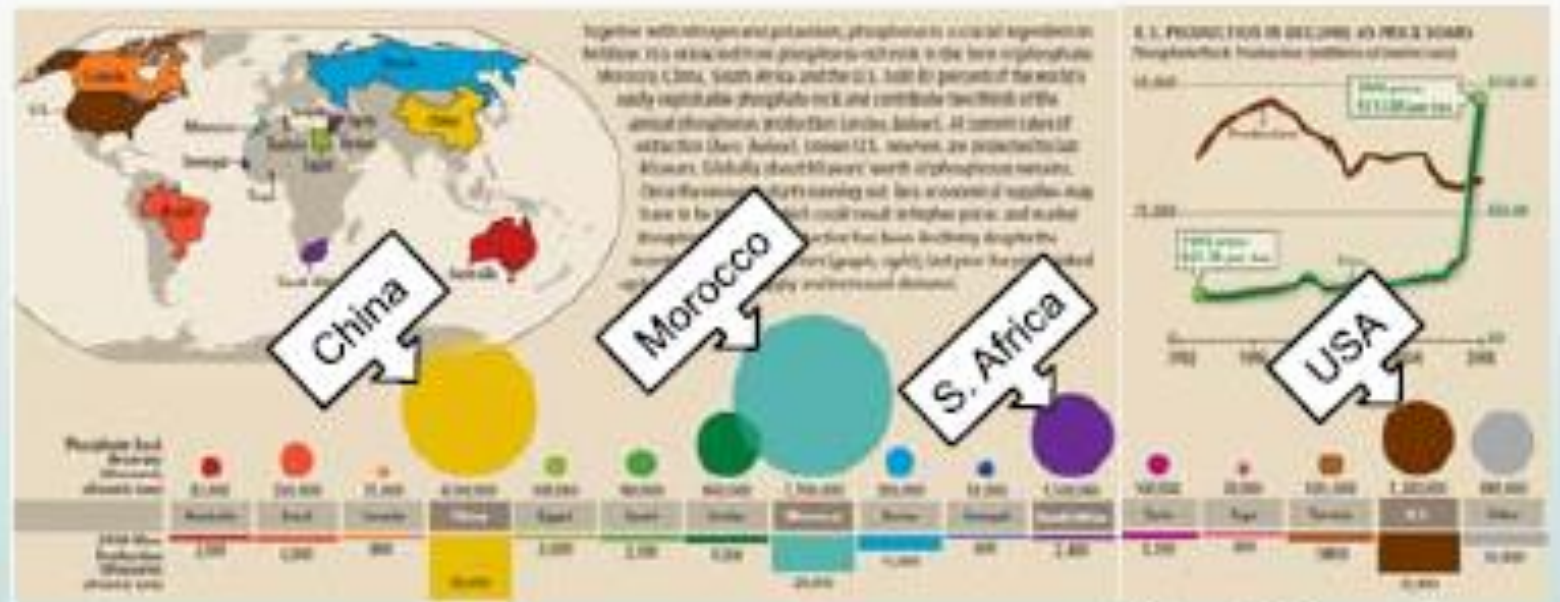
Absorption media often ineffective or expensive

Biological uptake used by plants (wetlands)



Phosphorus is Limited

Phosphorus Reserves and Production Worldwide



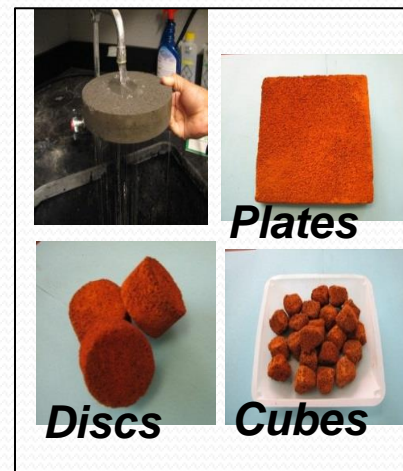
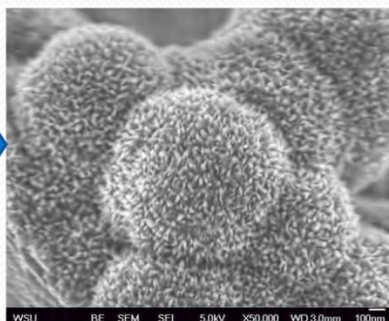
Vaccari, 2009

PO4 Removal & Recovery Product

Porous Media



Nano-Enhanced



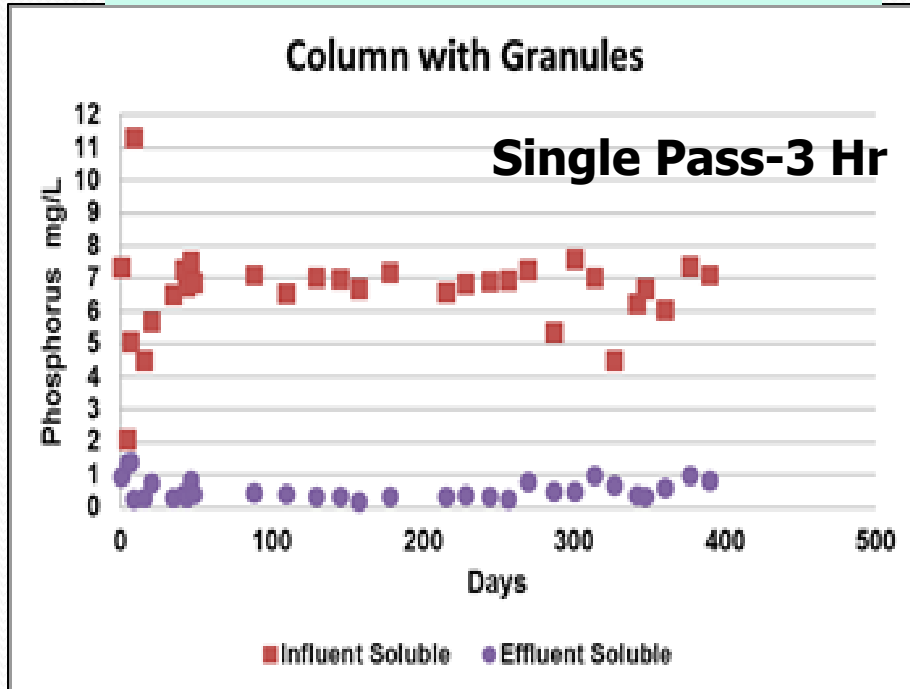
Nano-FeOOH Crystals in Porous Ceramics

Value Added

- ✓ **Holds much more P/Kg** than other sorbents
- ✓ **Works at high and low concentrations** (0.03 – 100+ mg/L)
- ✓ **Can reuse multiple times** (15-20)
- ✓ **Long Life & Cost Effective** for most applications
- ✓ **Phosphorus can be recovered**

PO4 Sponge Performance

Long Service Life



P below 1 mg/L – 400 d
P still removed
for another 220 days

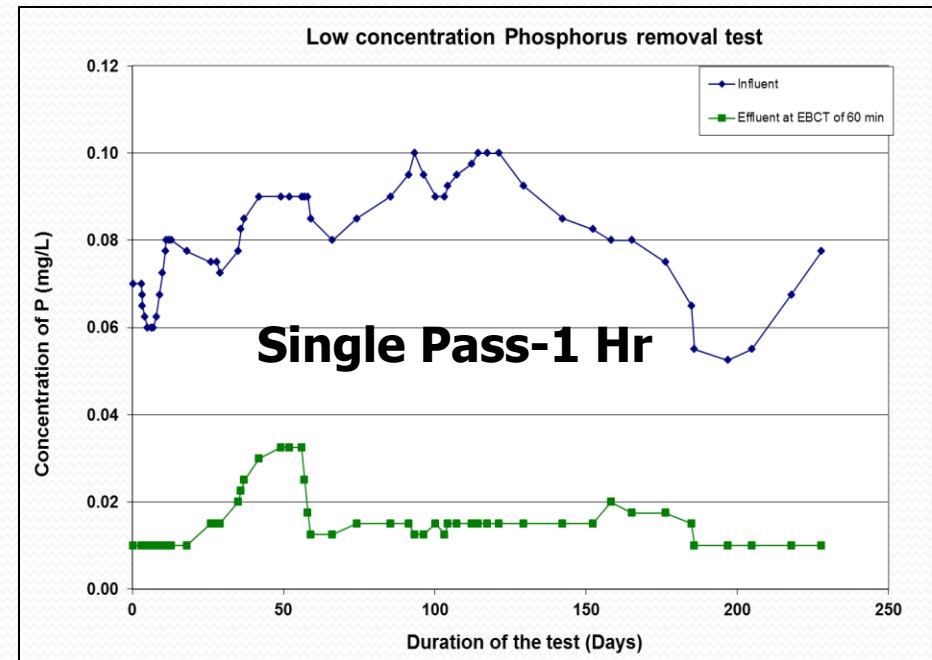
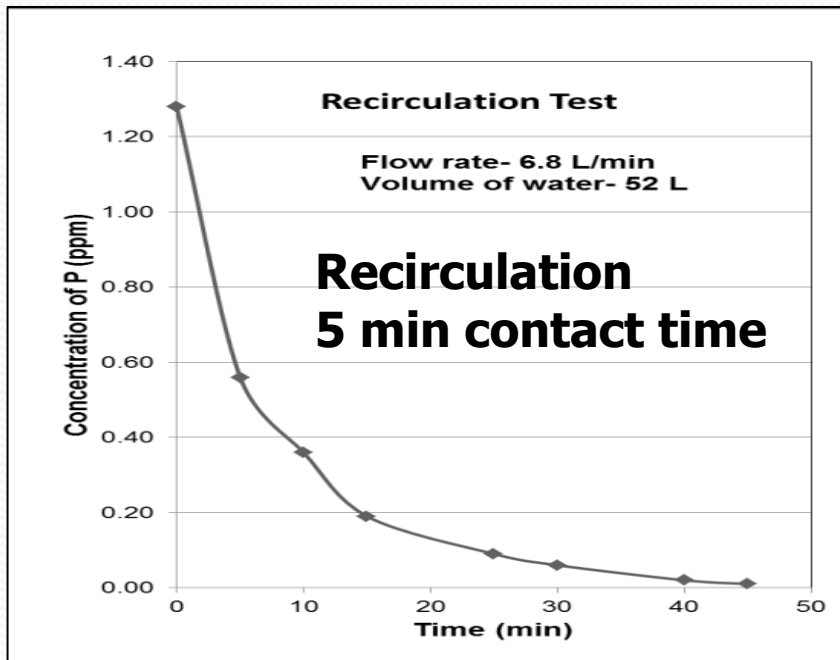
High Capacity

Sorption Media	mg-P/Kg
PO4 Sponge - Meta	
High > 5mg/L	80,000
Low < 2 mg/L	25,000
Iron Ore (Hematite)	1,430
Iron Slag	420
Crushed Red Bricks	510
LECA (expanded clay)	800
Activated Fe Alumina	17,100
Filtra-D	2,500
Phostec	7,000

Comparison
milligrams of P
per Kg Media

P04 Sponge Performance

P Removal under 0.1 mg/L

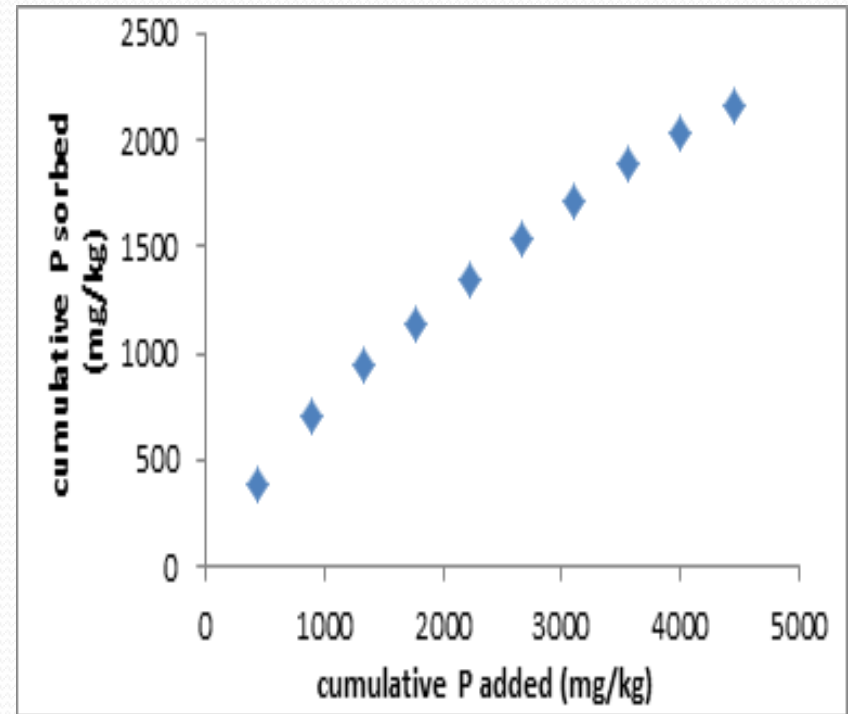
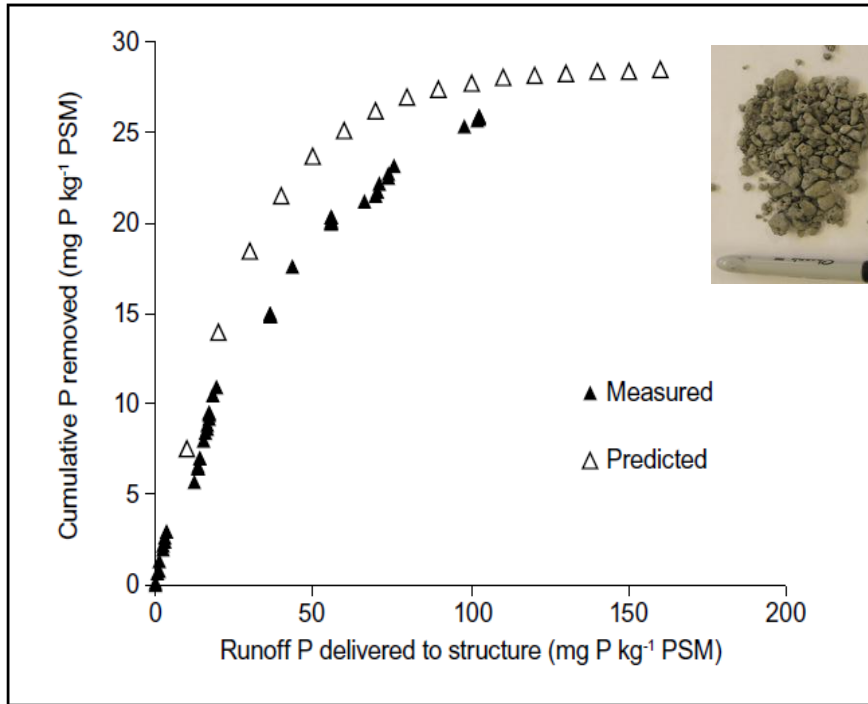


**P lowered 1.2 to 0.1 mg/L
in 25 min
to 0.01mg/L in 45 min**

**Over 220 days
Effluent < 0.02 mg/L
no sign of saturation**

Comparison with Iron Slag

40 X more Phosphorous Removal



P Removal – Iron Slag + Calcium
 Lab & Field Testing (3 Ton – 9” deep)
 Sorption stopped at 125 mg/Kg
 Total P sorbed under 30mg/Kg

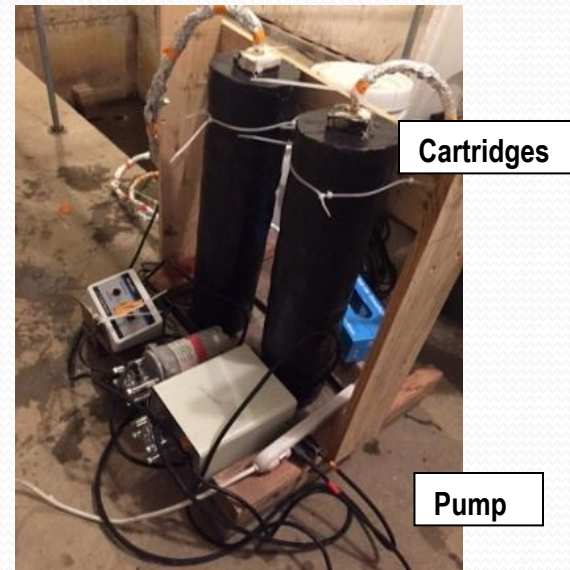
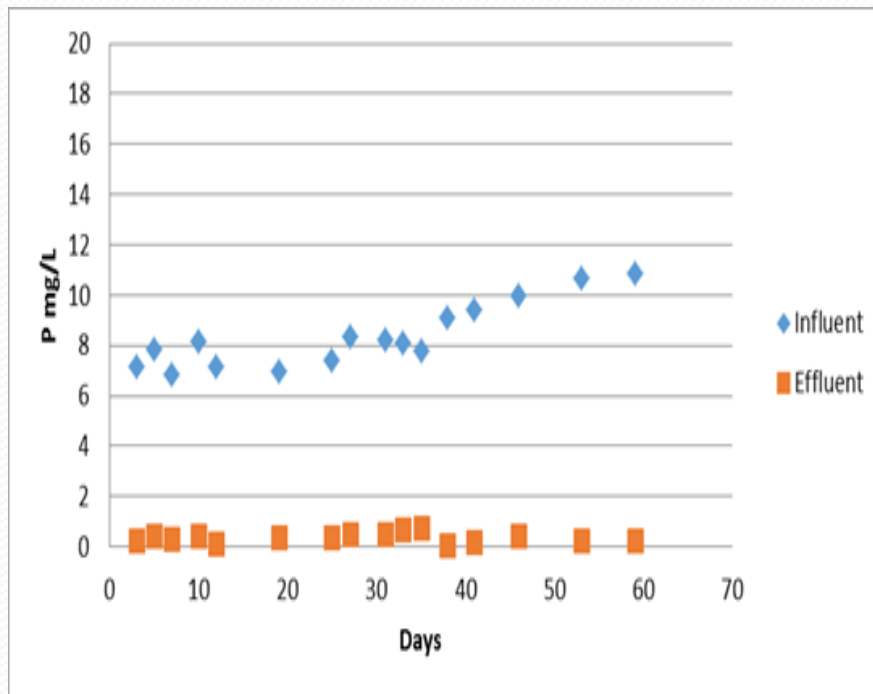
Source: Dr. Chad Peen – Ok State Univ.

P Removal – PO₄ Sponge
 Lab Testing
 Sorption on-going at 4500 mg/Kg
 Total P sorbed under 2300mg/Kg

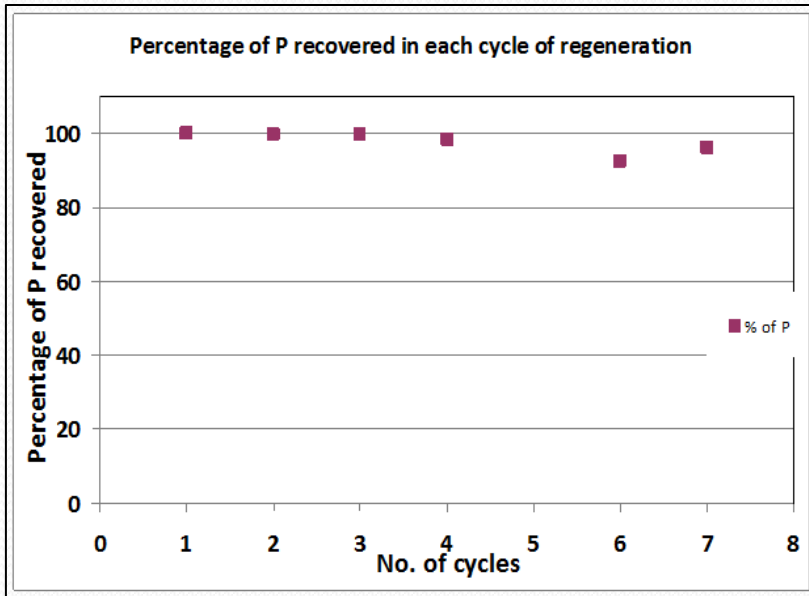
Source: Dr. Chad Peen – Ok State Univ.

Cartridge Testing

- Phosphorus Removed to Low Levels
 - 2 cartridges and pump at a 1.5 hour EBCT
 - Effluent P remained under 0.3 mg/L for a 60 day)

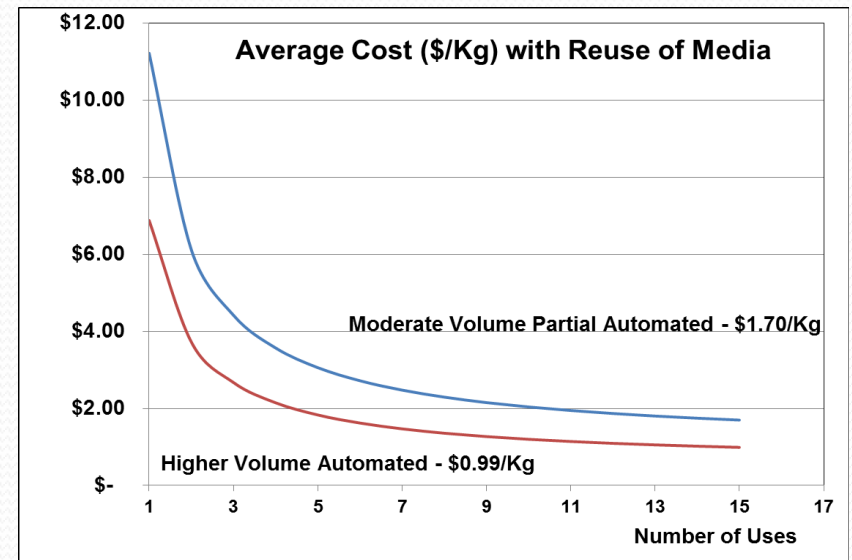


Remove PO_4^- & Reuse PO_4 Sponge 15-20 X



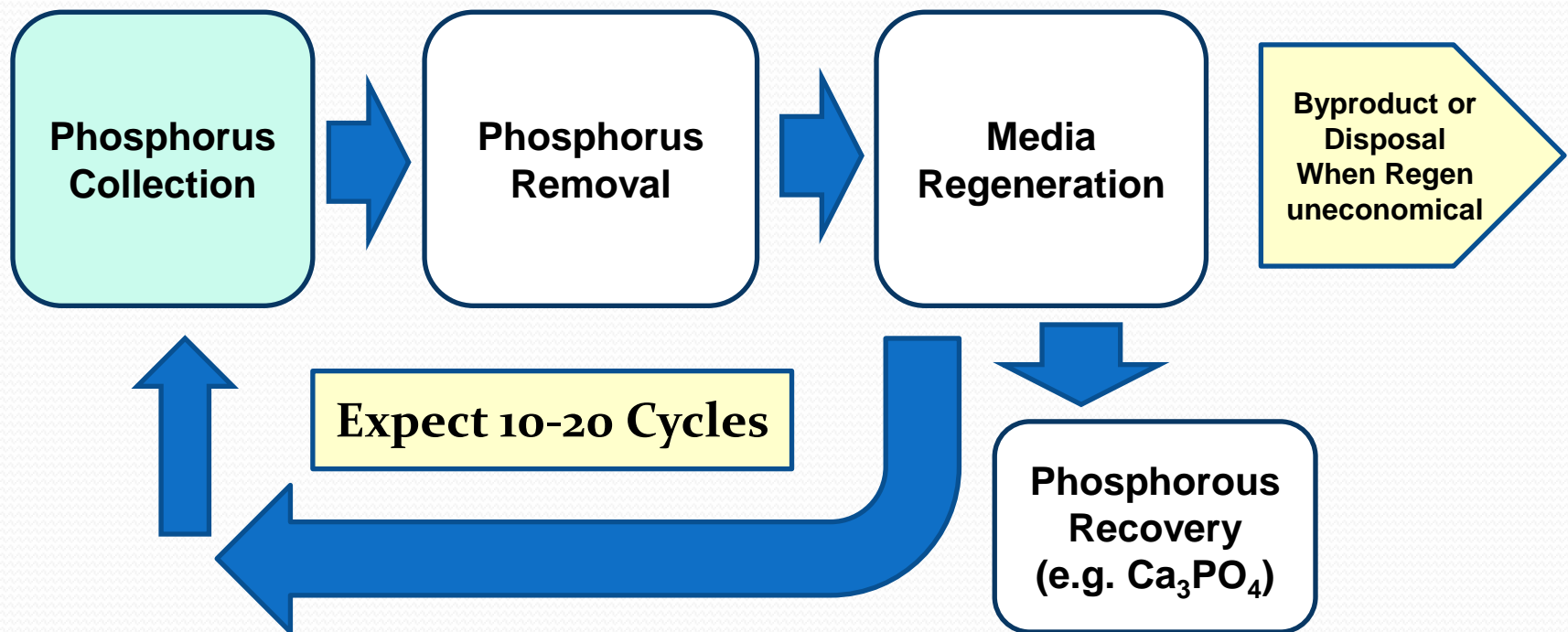
Capacity Sustained

Avg. Use Cost Lowered



PO₄ Sponge Use

Removal • Regeneration • Recovery

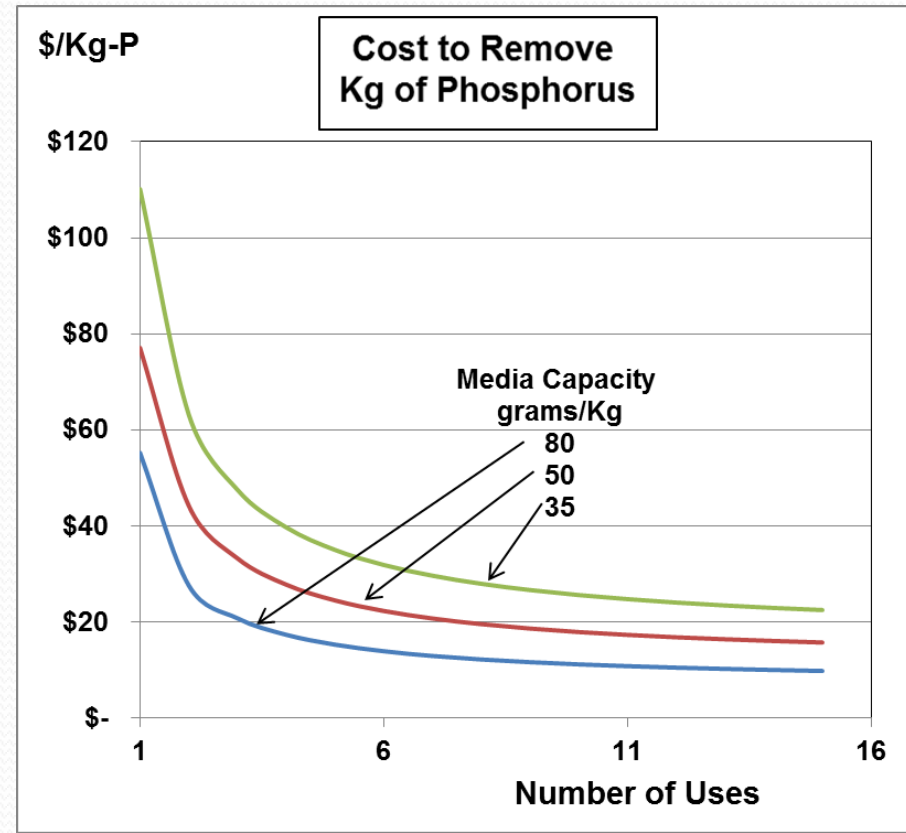


Recover Phosphorus

- **PO₄ Ions Removed from Media**
 - PO₄/NaOH – remove PO₄ to reuse NaOH
- **Precipitate as Calcium Phosphate**
 - Purity (depends on contaminants in water)
Analysis shows low impurities (Fe, Si, Al)
 - High phosphorous content
 - Fine particles (188 m²/gram) - easily processed
- **Low cost recovery Approach**
- **Calcium phosphate - feedstock material**
 - Used to make fertilizer, phosphoric acid

Cost to Remove (\$/Kg-P)

- **Cost to Remove Kg-P**
- **Depends On:**
 - Concentration of P
 - Cycle Time (before Regen)
 - No. of Media Uses
- **High Volume Production**
- **Results show Kg-P drops below \$20/Kg-P**
- **Lower than Chemical to lower below 0.5 mg/L**



Summary

Advantages of PO4 Sponge Media

- Has very **High capacity** for Phosphorous capture
- Excellent Way to **Harvest Phosphorus**
- **Regeneration/Reuse** makes Product Affordable
- PO4 Sponge **Cost Competitive** for many uses
 - Due to High Capacity & Multiple Uses
- **Phosphorous Recovery** Attractive
- **Commercialization through Partners** to accelerate technology use in U.S. and Overseas