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Removal and Recovery of Phosphorus from Wastewaters Using Mine Drainage Ochres

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Greater Everglades Ecosystem Restoration
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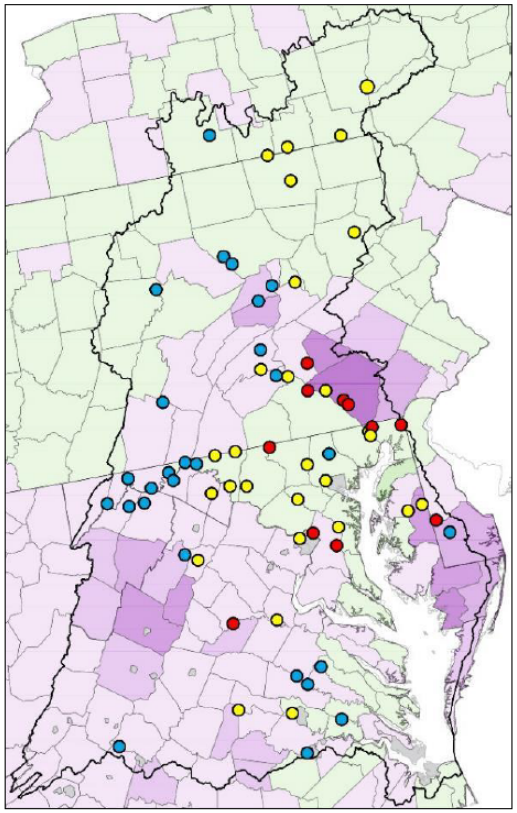
U.S. Department of the Interior
U.S. Geological Survey

Excess P in the Chesapeake Bay Watershed

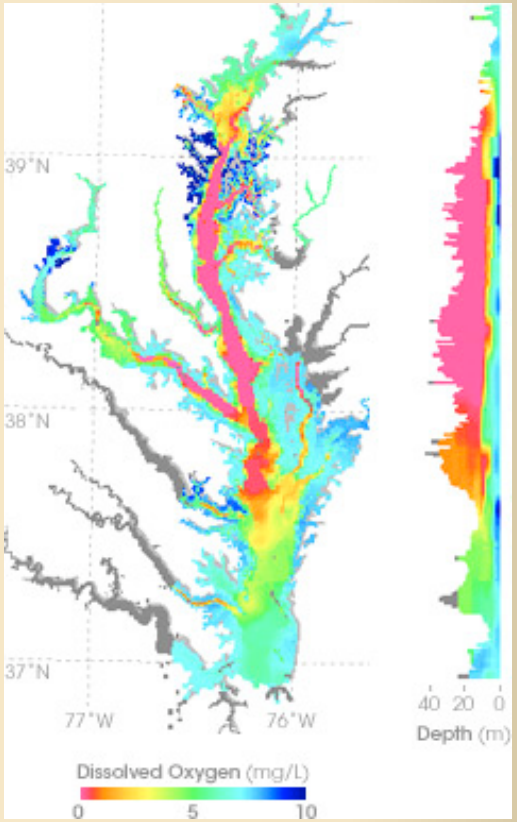
Watersheds with the highest nutrient per-acre loads have…

A long history of excess nutrient inputs, which can result in:

Phosphorus saturated soils. Phosphorus can be stored in soils when applications exceed crop removal rates. In areas where this has occurred, up to half of the total phosphorus load is exported in dissolved form[4].



From Moyer et al. 2018



Anoxic Dead Zones in Chesapeake Bay

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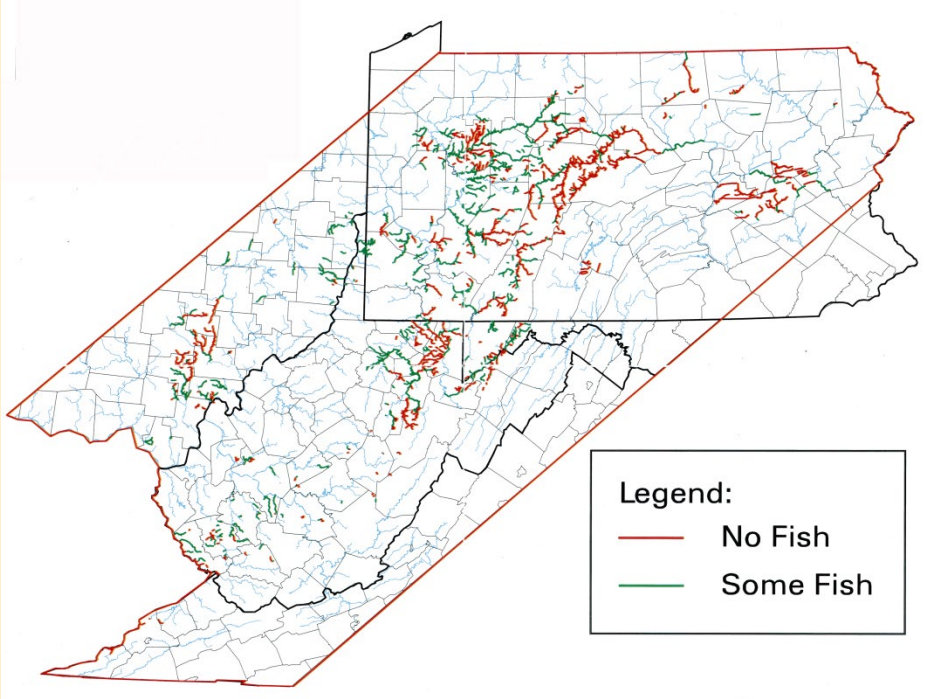
Acid Mine Drainage (AMD)

Coal/Pyrite + Air + Water →AMD



Over 5,000 stream miles impacted by AMD in the Appalachian region (EPA 1995)

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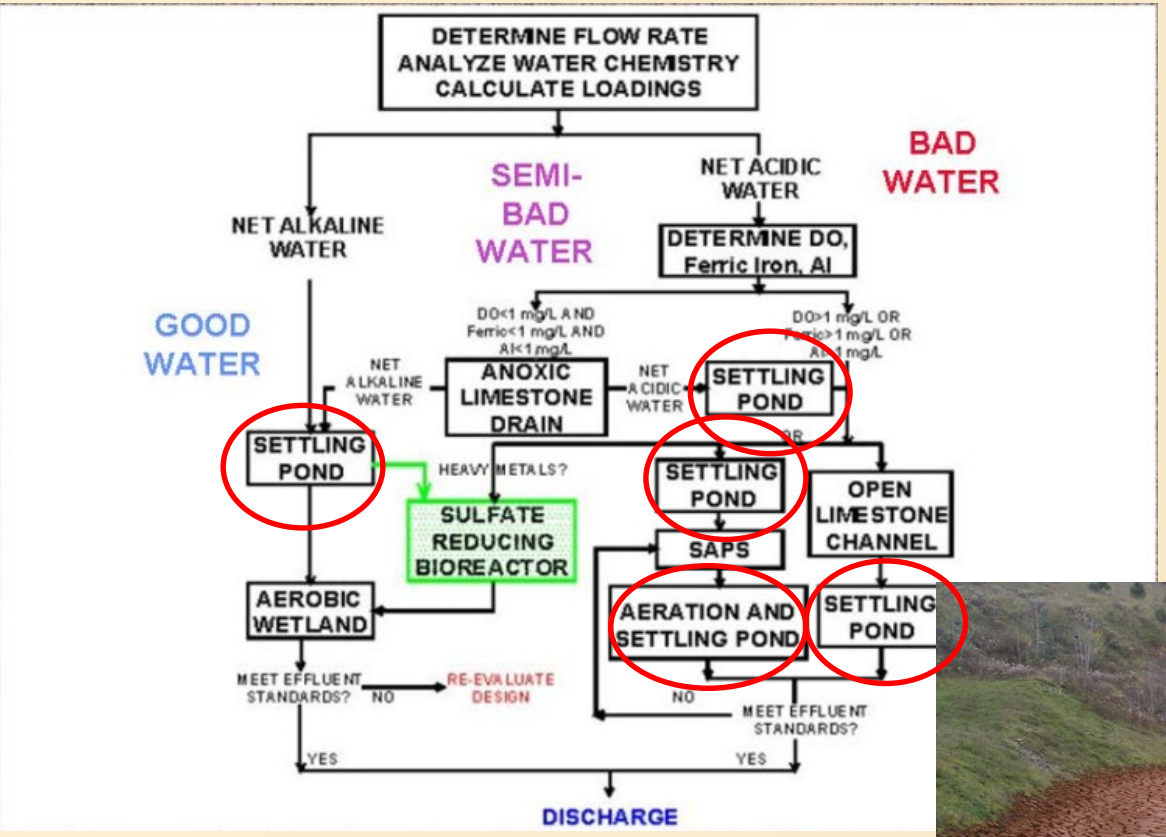
Treating AMD
You Always Get Iron Oxides (Ochres)



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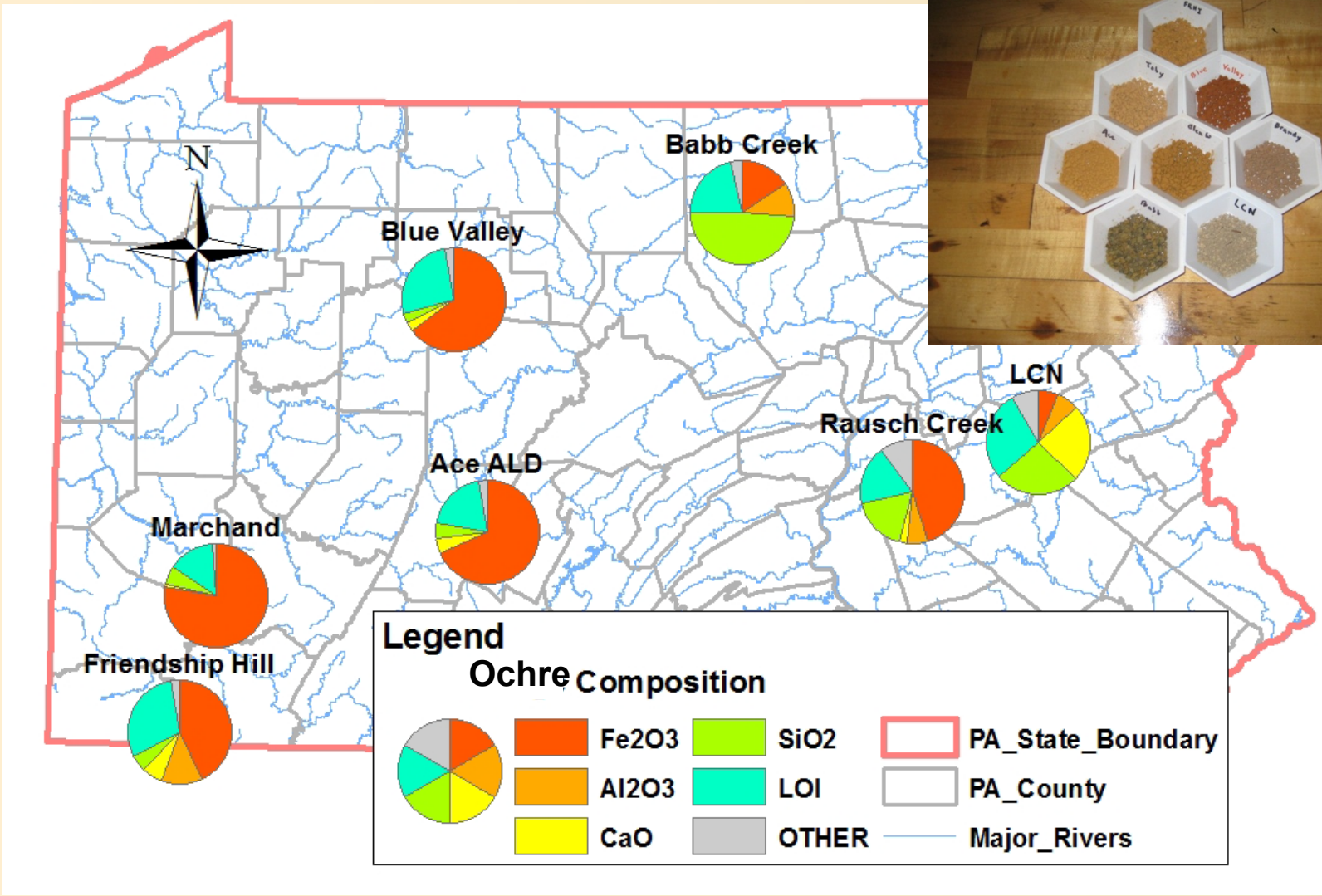
Why are we talking about AMD Ochres?



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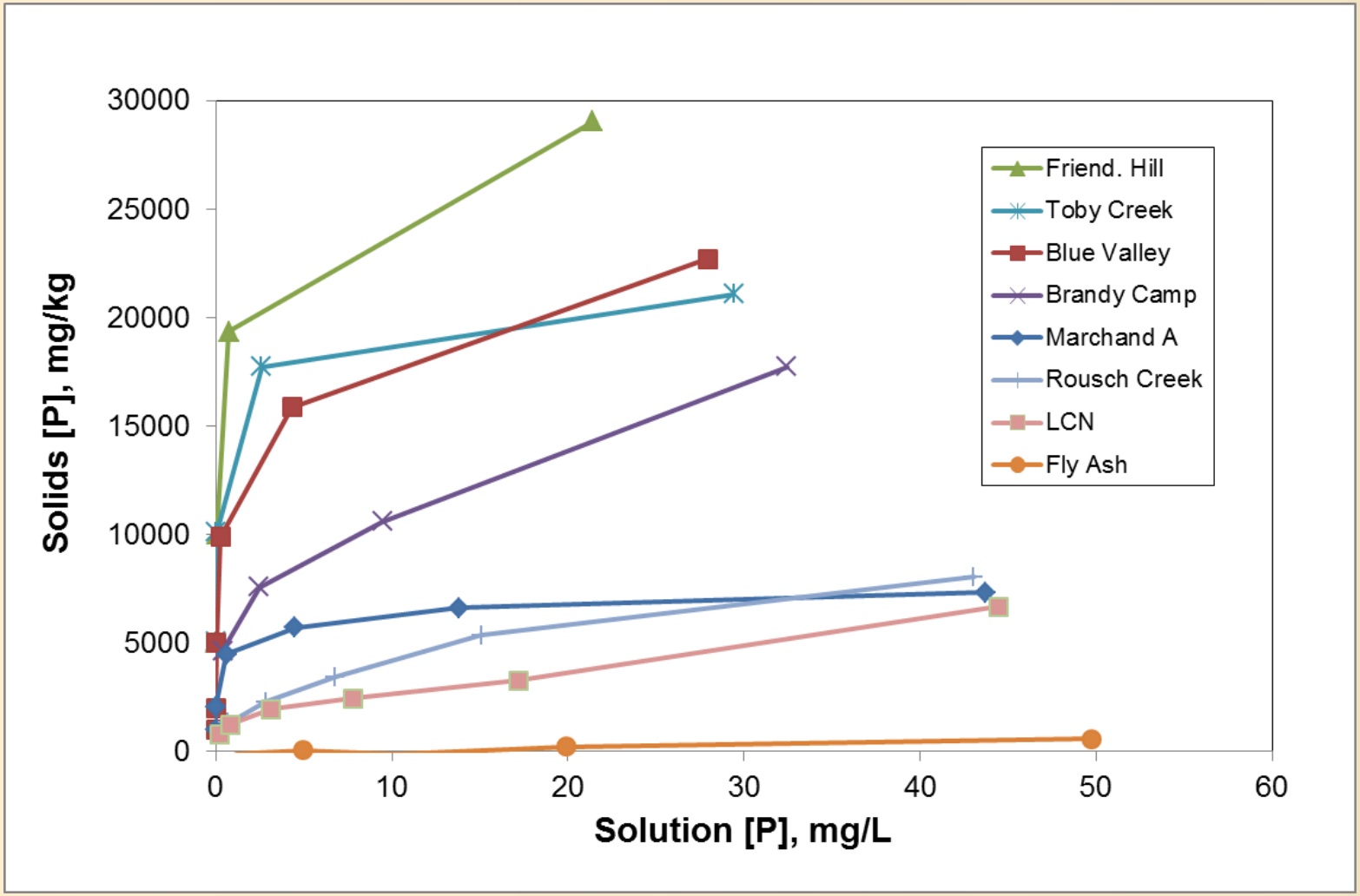
P Sorption Thermodynamics



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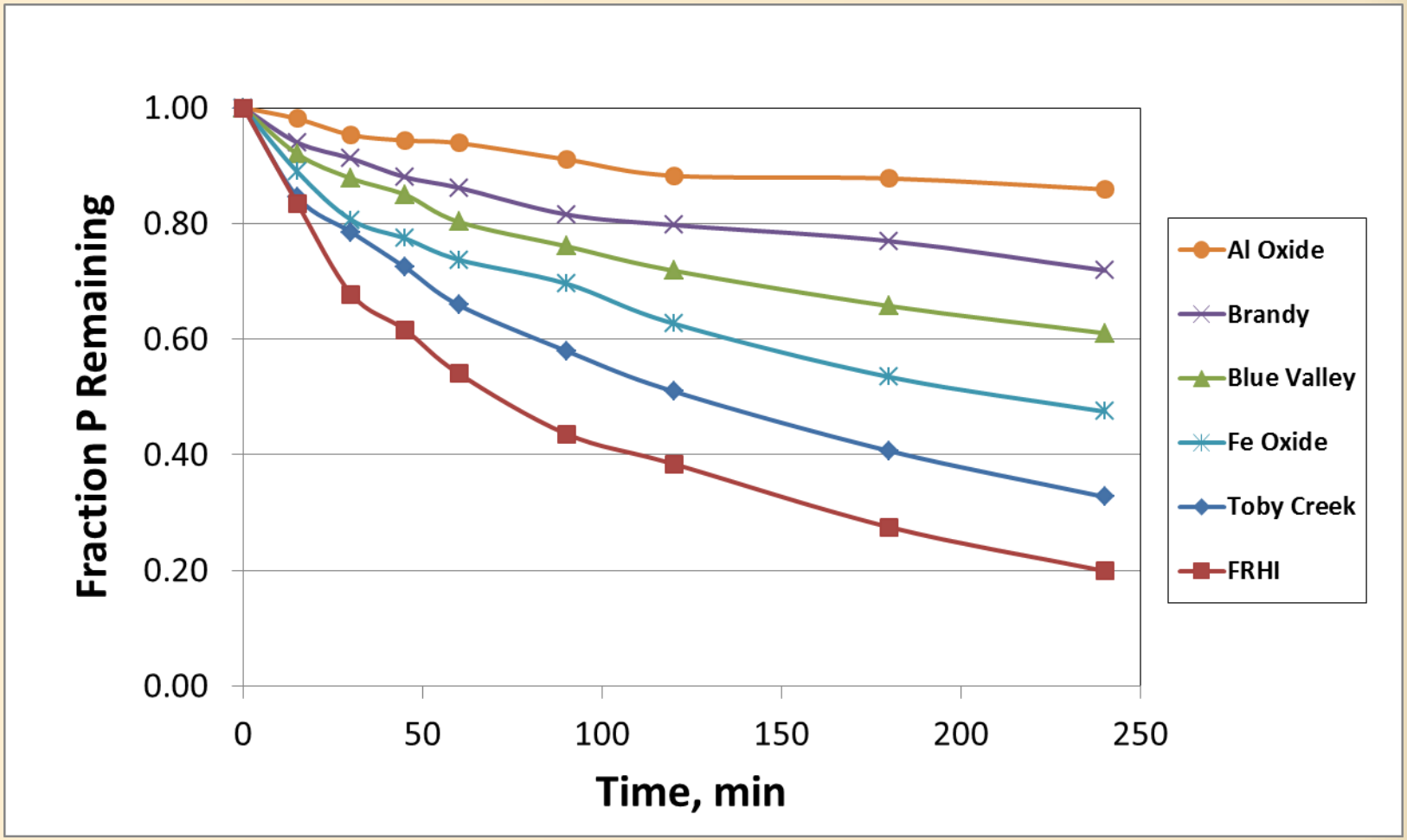
The Rate of P Removal from Water is Important, too.



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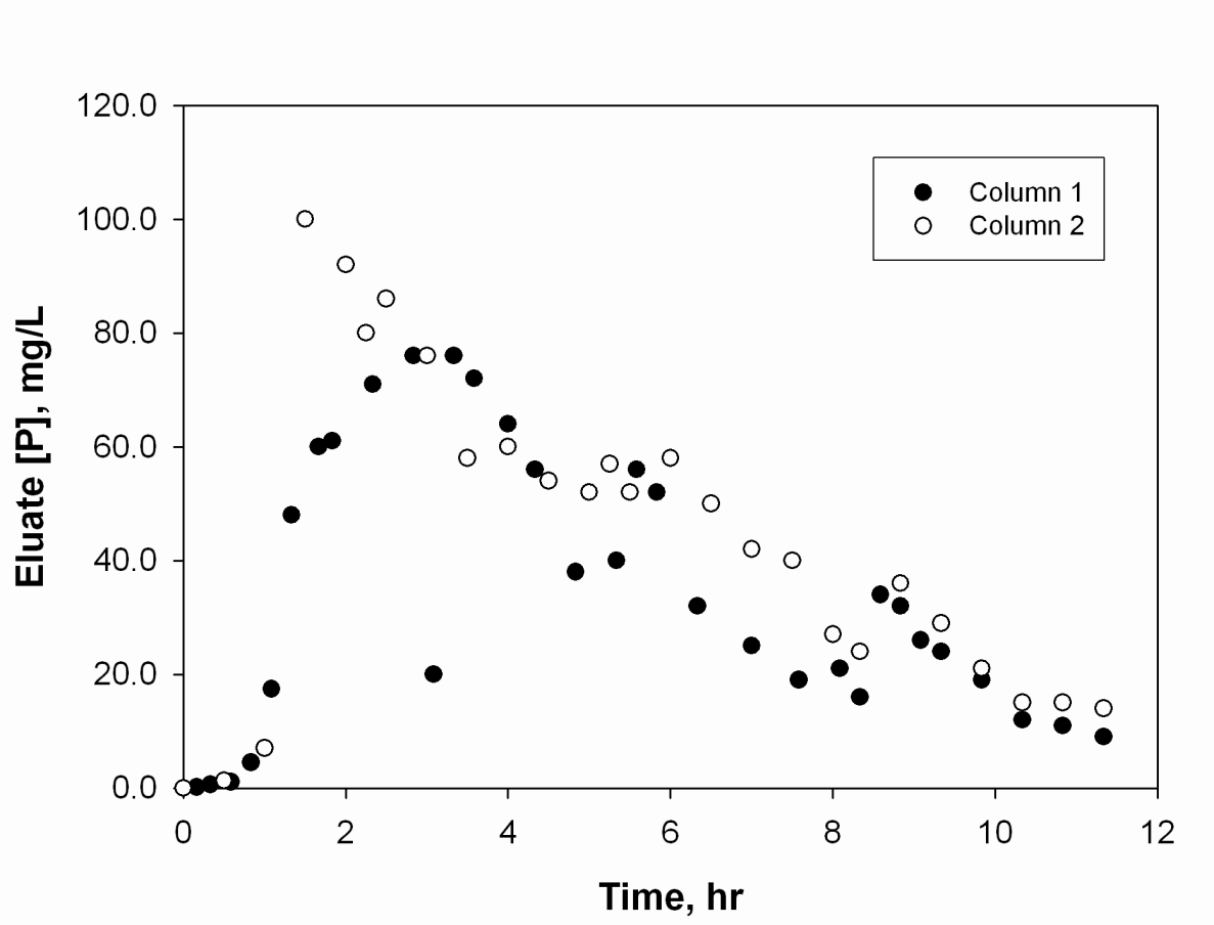
Phosphorus Stripping (Lab)



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Strip solution (0.5 M NaOH) removed 76% of P, and concentrated it up to 1000-fold.

P Removal Technologies

- Addition of Fe or Al salts
  - Requires purchase of reagent, i.e. alum, $FeCl_3$, or similar
  - Requires solid/liquid separation after dosing, sludge disposal
- Biological P uptake/wetlands
  - More complex treatment configuration
  - Difficult to retrofit to existing plants
  - Extensive land area

P Removal Technologies

- Fixed-bed P removal
  - Use ochre (waste product) for sorption media
  - No solid/liquid separation
  - Recovery and recycle of P
  - Regenerate media
  - Ability to add to existing system

What About Water Contamination?

Sludge Source	Al mg/L	Ca mg/L	Fe mg/L	K mg/L	Mg mg/L	Mn mg/L	Na mg/L
Friendship Hill	<1	51.1	<1	<5	1.48	<0.01	<1
Toby Creek	<1	9.7	<1	<5	0.74	0.01	<1
Brandy Camp	<1	9.7	<1	<5	4.06	<0.01	<1
Glen White	<1	1.8	<1	<5	0.19	0.07	<1
Ace ALD	<1	10.3	<1	<5	<0.05	<0.01	<1
Babb Creek	<1	0.6	<1	<5	<0.05	0.03	<1
MDL	1	0.5	1	5	0.05	0.01	1

Sludge Source	As mg/L	Cd mg/L	Co mg/L	Cu mg/L	Ni mg/L	Pb mg/L	Zn mg/L
Friendship Hill	<0.05	0.002	0.02	<0.01	0.02	<0.05	0.06
Toby Creek	<0.05	<0.001	<0.02	<0.01	<0.01	<0.05	0.08
Brandy Camp	<0.05	<0.001	0.04	<0.01	0.01	<0.05	0.06
Glen White	<0.05	<0.001	0.02	0.01	0.02	<0.05	0.14
Ace ALD	<0.05	<0.001	<0.02	<0.01	<0.01	<0.05	<0.01
Babb Creek	<0.05	<0.001	<0.02	<0.01	0.02	<0.05	0.16
MDL	0.05	0.001	0.02	0.01	0.01	0.05	0.01

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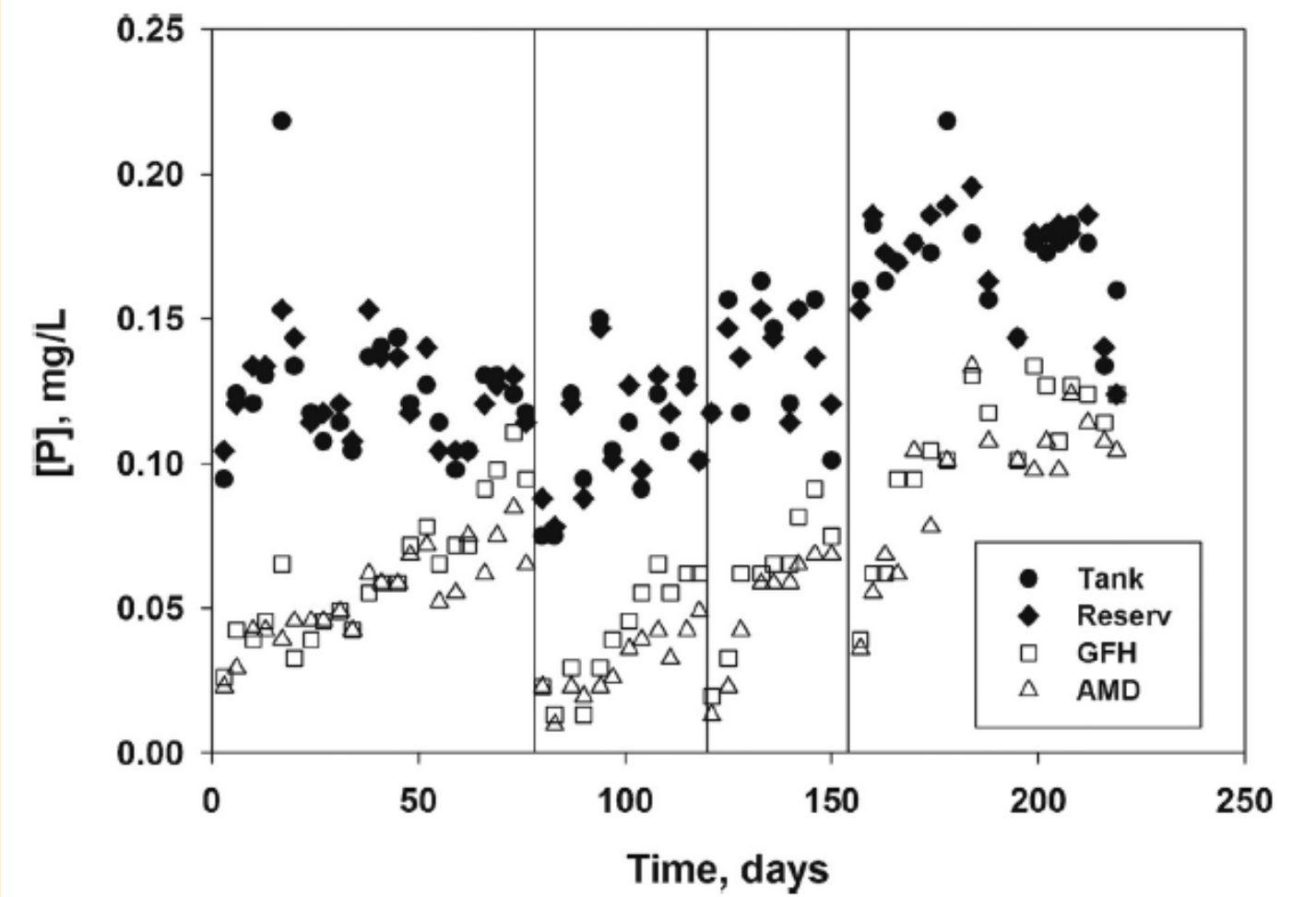
USFWS NEFC– 1440 gallons per day



Results:

- **223 days operation total**
- **Average flow of 1 gal/min (1440 gal/day)**
- **320,000 gal treated (88,000 bed volumes)**
- **56% overall P removal (91 g P)**

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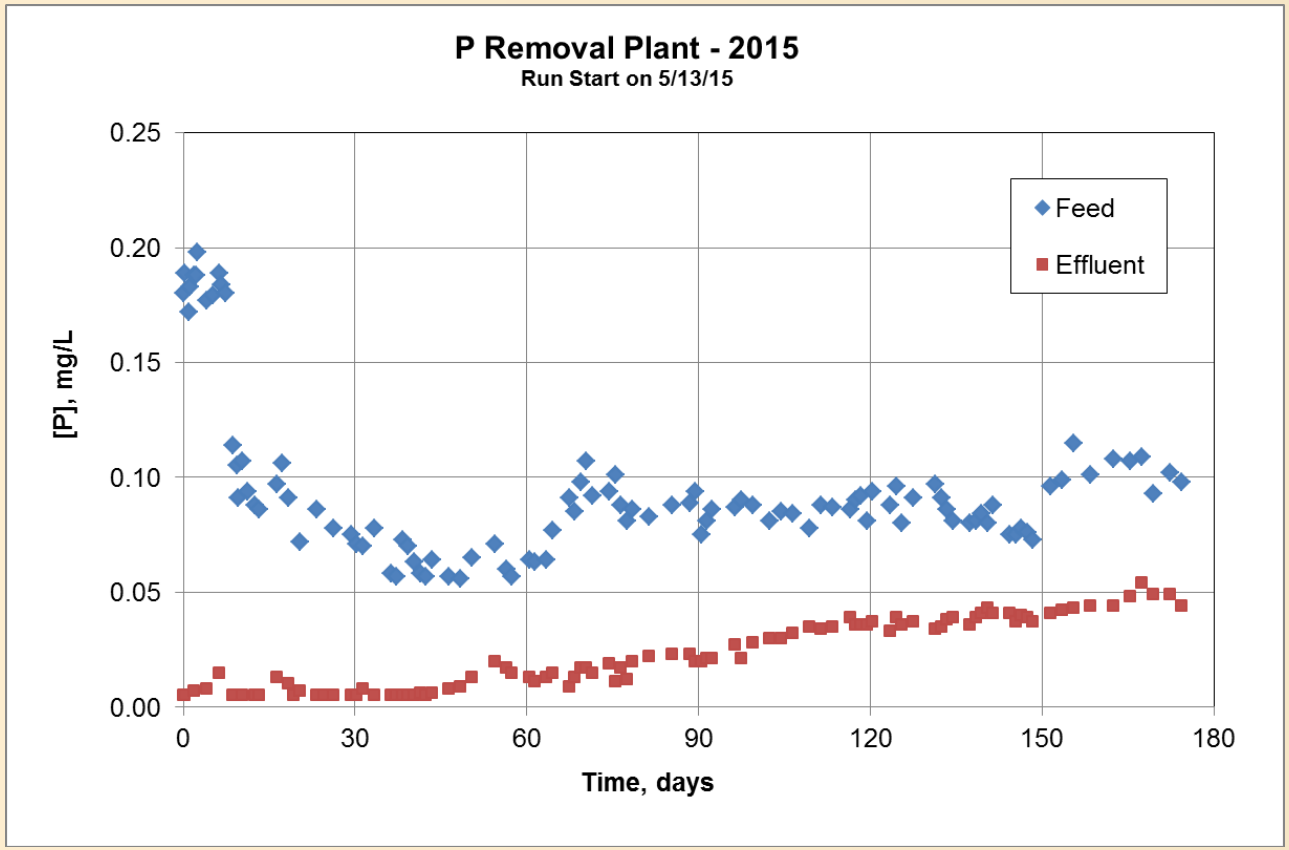
Scale-up: 100,000 gallons per day

USDA-ARS Broodstock Facility, Kearneysville, WV

- 20,000 fish (4000 kg)
- 150 gpm makeup water

Full Scale Plant–Results



Results:

- **174 days operation w/o regeneration**
- **Average flow of 53 gal/min (75,000 gal/day)**
- **13.2 MM gal treated (26,800 bed volumes)**
- **73% overall P removal (7.2 lb P)**

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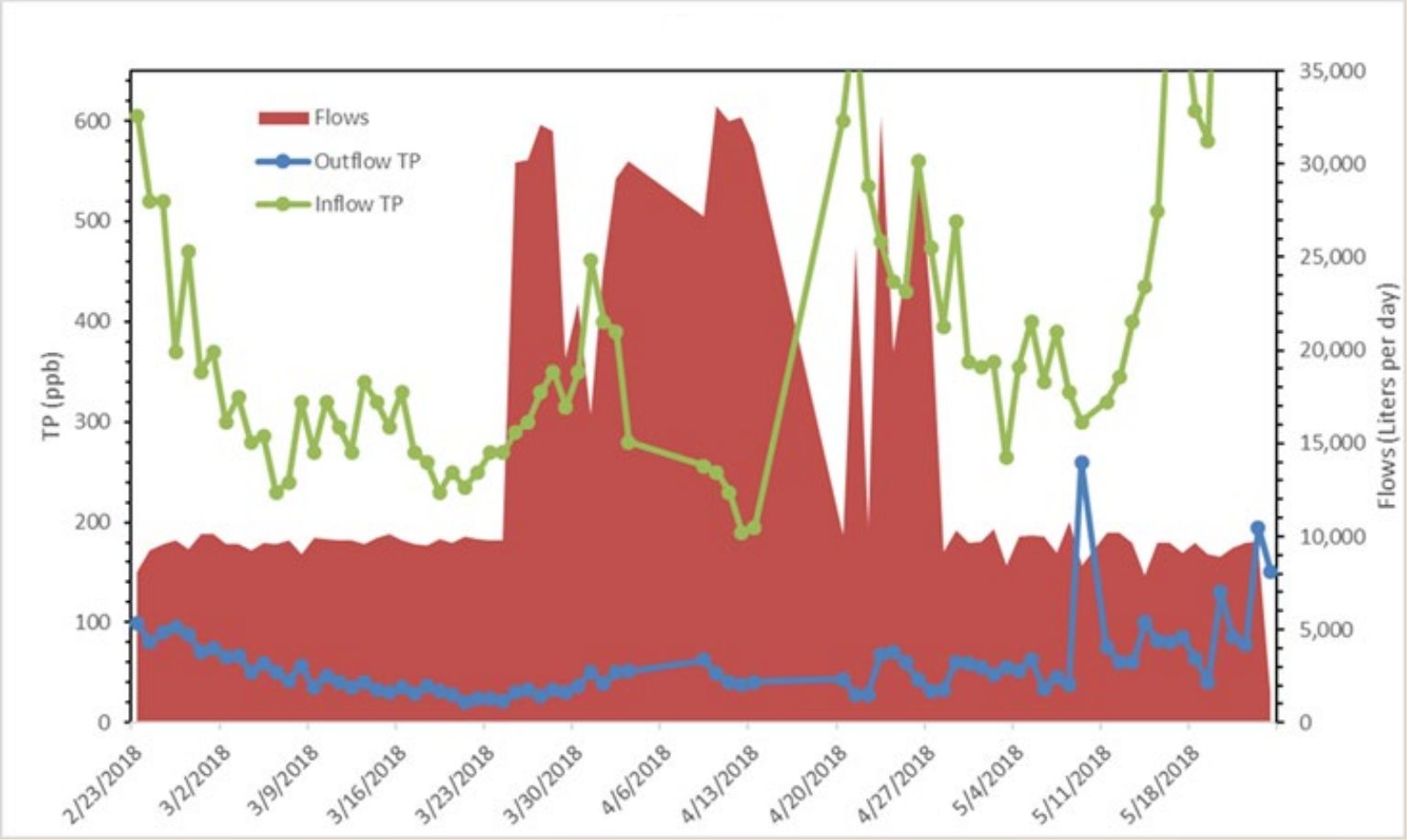
George Barley Water Prize – Stage 3 Canada Pilot



Results:

- **91 days operation w/o regeneration**
- **Flow range: ~9,500-32,000 L/d**
- **Mean TP influent 354 ug/L**
- **87% overall P removal**

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Summary

- Mine drainage ochres are a low-cost source of iron/aluminum oxides that have a high affinity for P.
- Fixed bed sorption trials indicate that effective P removal is possible over days to months of operation.
- Phosphorus can be stripped from the media, precipitated, and recycled to agricultural applications.
- The sorption media can be regenerated and reused for many cycles of sorption and regeneration, thus leading to decreased operating costs.
- Applicable to various wastewater sources.

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Thank you!
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