Modeling of Phosphorus Attenuation Mechanisms in Soil Based Septic Systems

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Project Goals

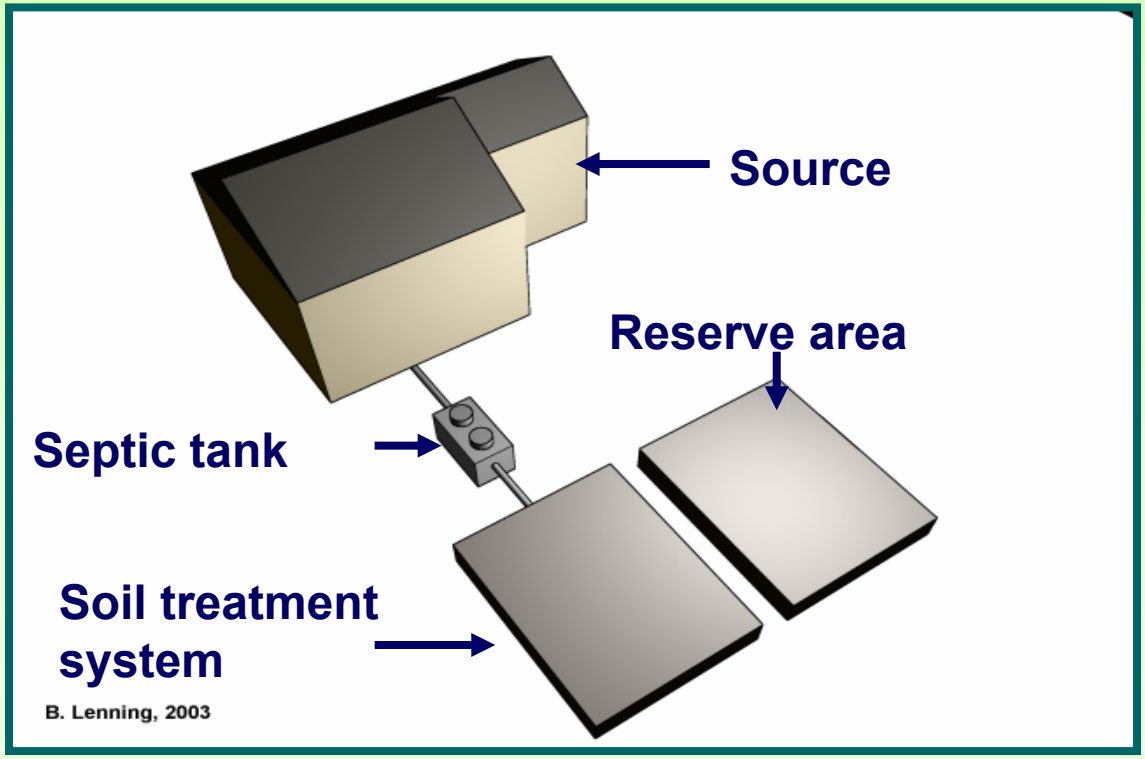
- Improve the understanding of subsurface transport and transformation of Phosphorus (P)
- Two attenuation mechanisms will be studied:
  - soil sorption of P
  - chemical precipitation of P mineral compounds
  - synergistic effect
- This project will help to:
  - More fully understand the attenuation of phosphorous in soils
  - Results may be useful to determine if additional treatment or greater setbacks to surface water are necessary.

Phosphorus and Wastewater

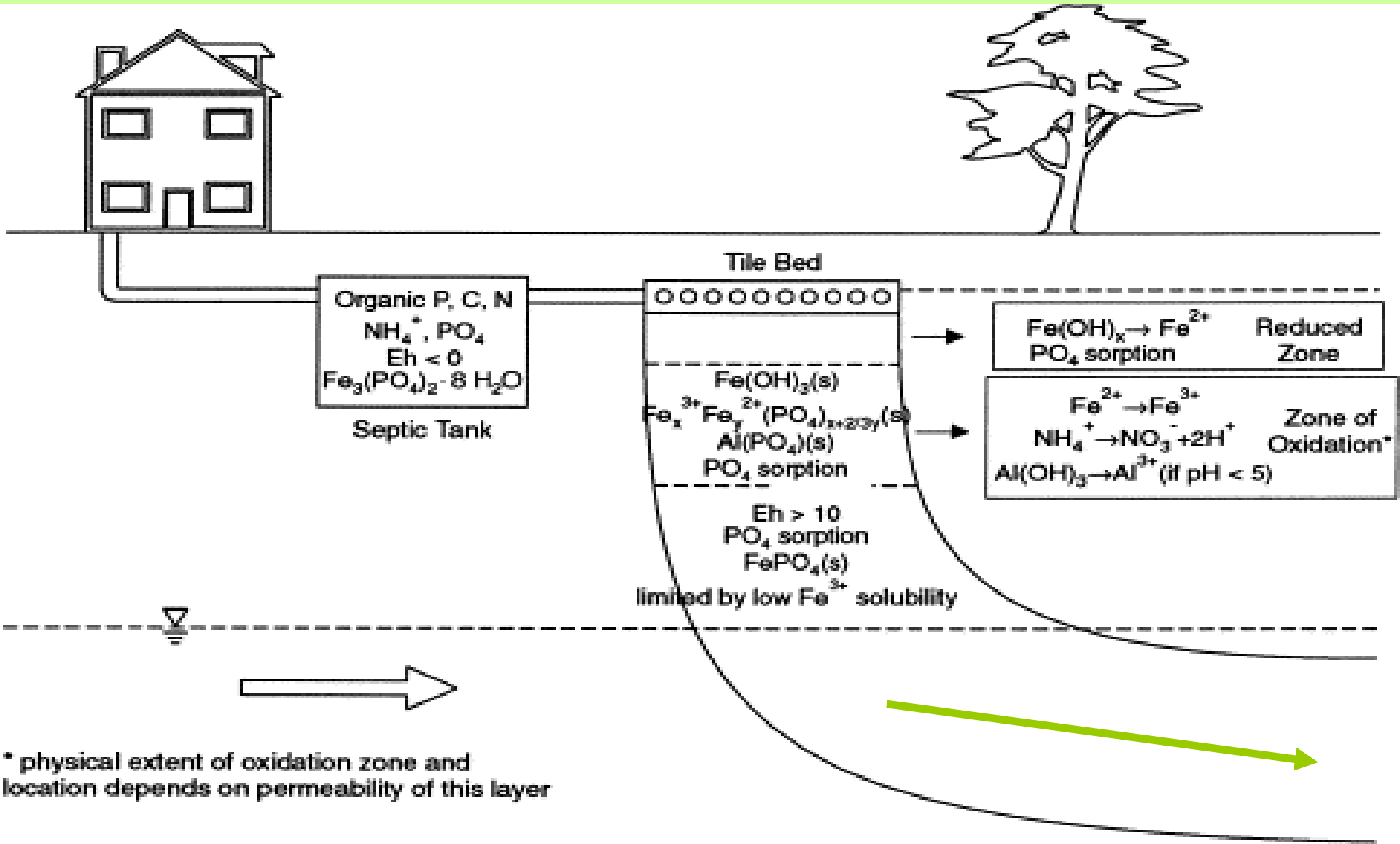
- P from onsite wastewater systems (OWS) is often considered to be a water resources problem because of potential eutrophication of sensitive wetlands or other surface-water bodies.
- This concern is growing in areas when:
  - Clustered (>2,500 gpd) OWS are being installed
  - Around lake shores particularly with sandy soils
  - Areas where TMDLs for P have been established

Anatomy of a Septic System

- **Plumbing**: wastewater collection
- **Septic tank**: primary treatment
- **Soil treatment system**: final treatment and dispersal



P Forms and Processes in OWS



Phosphorus

Species

Particulate

Living and Dead Aquatic Life
Precipitates
Adsorbed to Particles

Soluble

Excretion (typ. Adult: 1.2 lb/day)
Manure and Fertilizers
Cleaning Products
Water Conditioning (prevent scaling)

Phosphorus

Species

Organic

Bound to Plant and Animal Tissue
Breakdown of Organic Pesticides

Inorganic

Orthophosphate (Reactive)

*$H_2PO_4^-$, **HPO_4^{-2}**, and PO_4^{-3}*

Polyphosphate

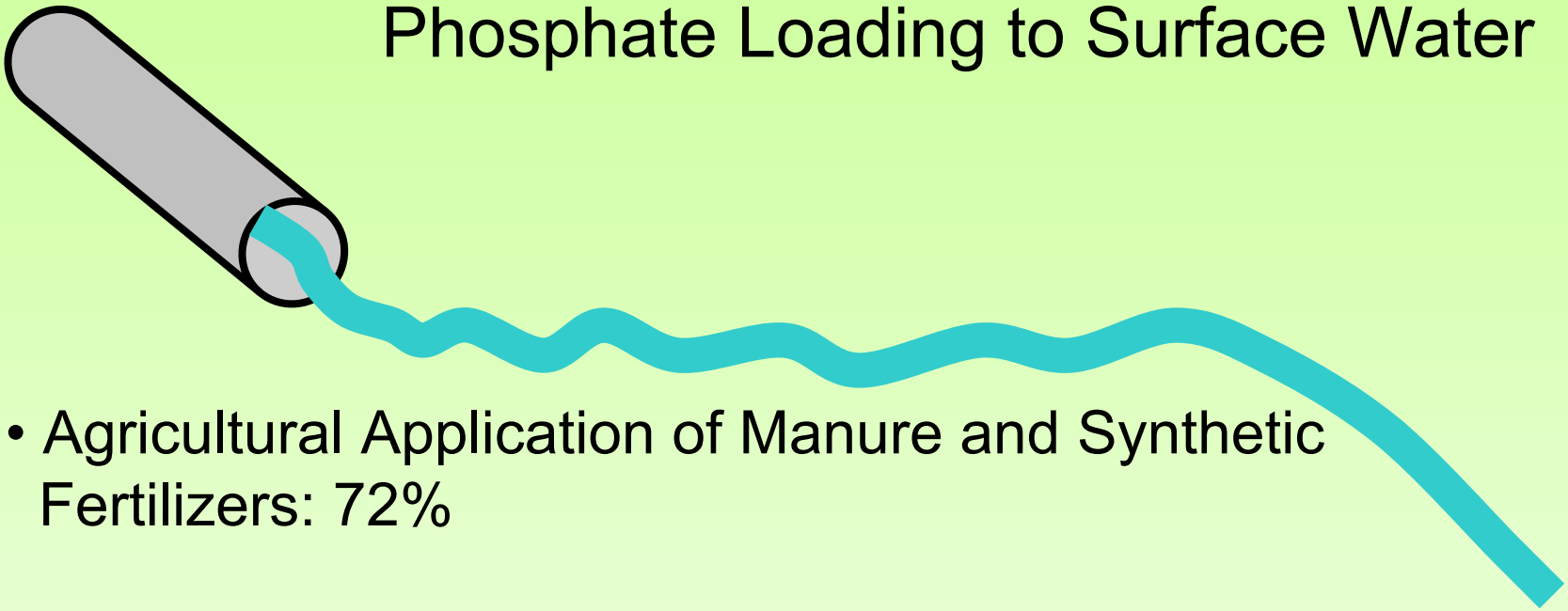
sodium hexametaphosphate [$Na2(P_2O_3)_6$]
sodium tripolyphosphate [$Na_3P_3O_{10}$]

In water, unstable and will convert by hydrolysis

Interest: Soluble, Orthophosphate

Phosphorus

Source



Phosphate Loading to Surface Water

- Agricultural Application of Manure and Synthetic Fertilizers: 72%
- Wastewater Treatment Plant Effluent: 5%
- Onsite Wastewater Treatment Systems: 4-25%

Lombardo P. (2006). *Phosphorus Geochemistry in Septic Tanks, Soil Absorption Systems, and Groundwater*. Prepared by Lombardo Associates, Inc., Newton, MA.

Phosphorus

Impact

- Limiting Nutrient that Controls Eutrophication
- Increases the Potential for Toxic Algal Blooms
- Increase Turbidity and Sedimentation
- Impacts the Value of Waterfront Dwellings
- Reduces Recreational Value of Water Bodies

Phosphorus Removal Techniques

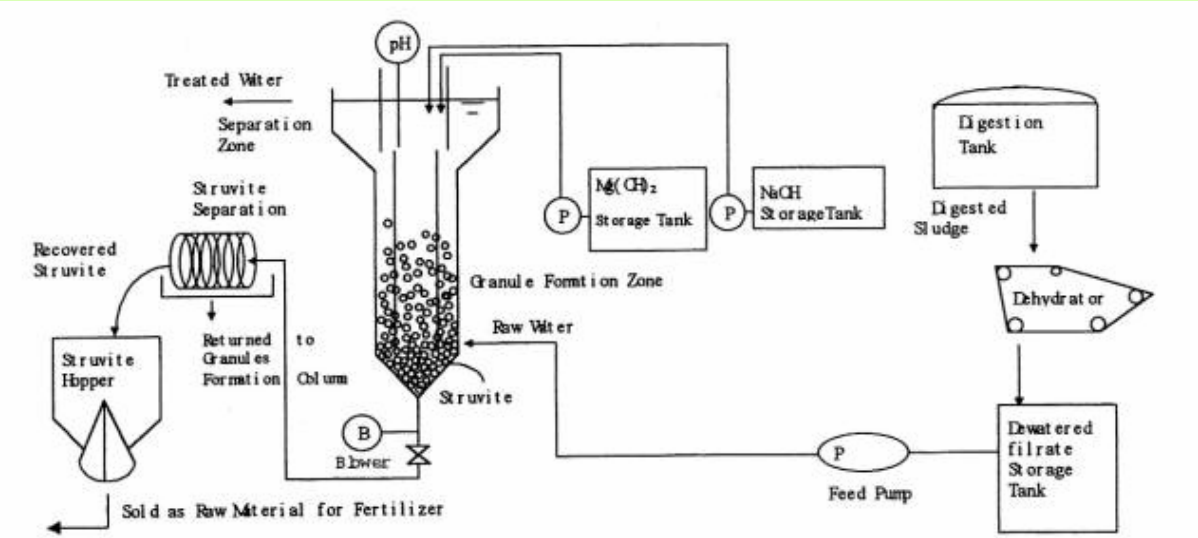
Soluble

- Struvite Crystallization
- Biological
- Precipitation
- Soil Absorption
- Sorption

Phosphorus Removal Techniques

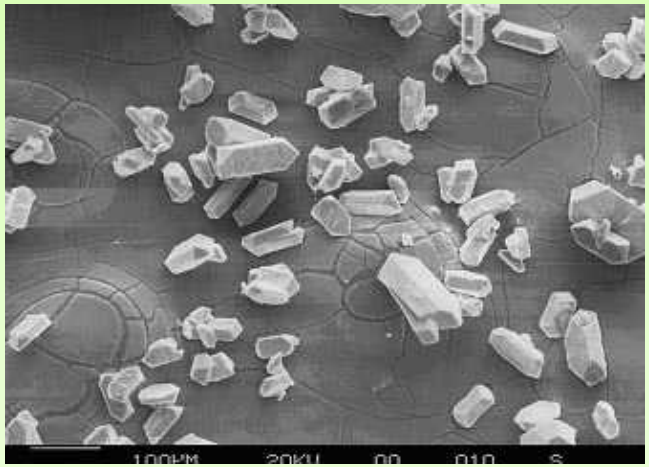
Struvite Crystallization

Magnesium Ammonium Phosphate ($MgNH_4PO_4$) Complex Formed with Supersaturated Phosphate Levels Under Basic pH



Phosnix - process design at WWTP Shimane Prefecture Lake Shinji East (Unitika Ltd.)

STOWA Struvite Recovery Sheet, http://www.stowa-selectedtechnologies.nl/Sheets/Sheets/Struvite.Recovery.html



Granfield University, Center for Water Science, http://wwwlegacy.cranfield.ac.uk/sas/water/scale/struvite.htm

Phosphorus Removal Techniques

Biological

Anaerobic

→

Aerobic

→

Biosolids Removal

Phosphorus Removal Techniques

Precipitation

Alum

$$Al_2(SO_4)_3 \cdot 14H_2O + 2PO_4^{3-} \rightarrow 2AlPO_4 \downarrow + 3SO4^{2-} + 14H_2O$$

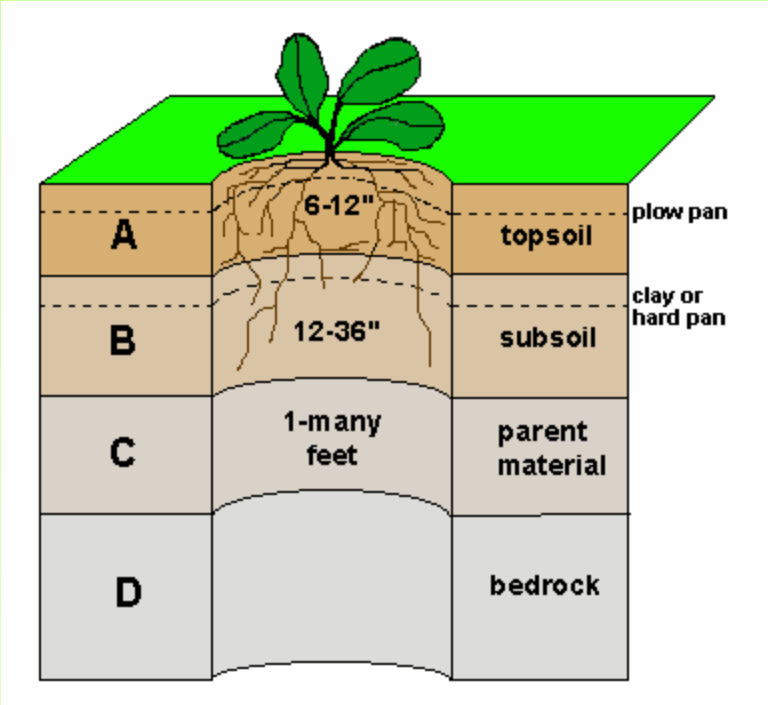
Ferrous Chloride

$$3FeCl_2 + 2\,PO_4^{3-} \rightarrow Fe_3(PO_4)_2 \downarrow + 6Cl^-$$

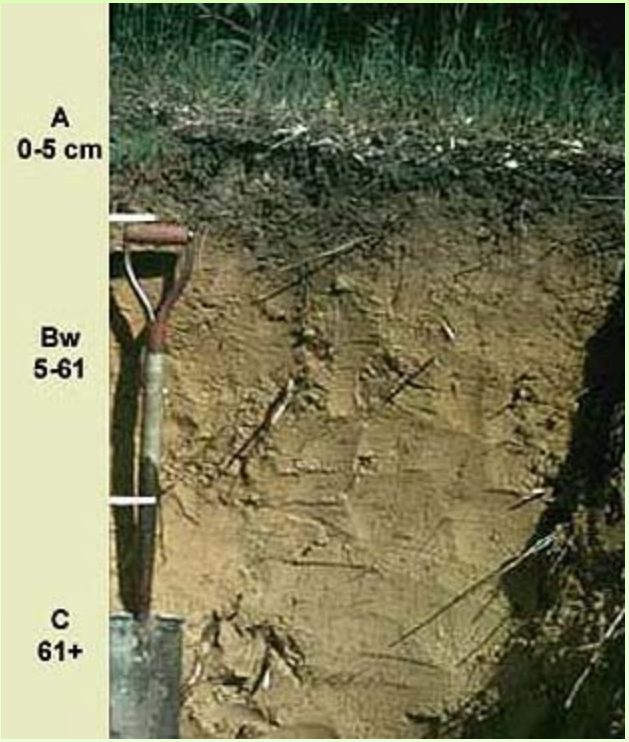
Phosphorus Removal Techniques

Soil Absorption

Absorbed in Soil B Horizon (6-24 inches deep) by Aluminum, Clay, Oxidized Iron or Carbonates



Delta Mine Training Center Integrated Soil Module
http://www.dmtcalaska.org/exploration/ISU/unit2/u2lesson1.html

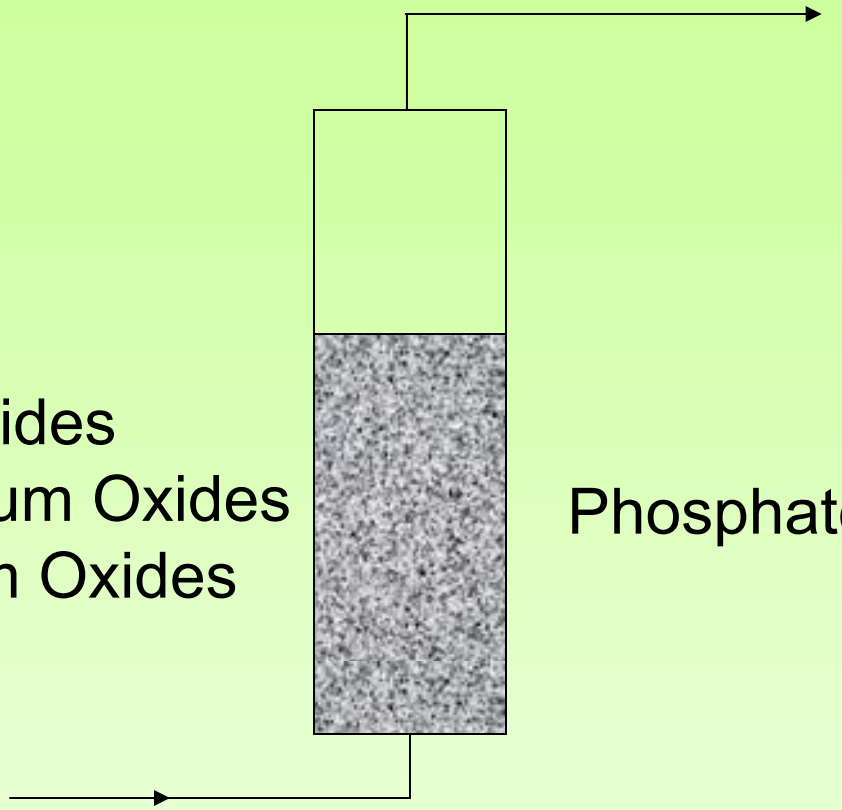


University of Idaho College of Agricultural and Life Sciences, The Twelve Soil Orders, Soil Taxonomy, http://soils.ag.uidaho.edu/soilorders/entisols_08.htm

- Adequate Soils
- Capacity for Long Term
- Monitoring

Phosphorus Removal Techniques

Sorption



Iron Oxides
Aluminum Oxides
Calcium Oxides

Phosphate Metal Complex

- Multiple Charged Cations to Attract Phosphates
- Form Surface Hydroxides that can Exchange with Phosphates
- Form Mineral Complexes with Orthophosphate

Sorption

Criteria

Effectiveness

- Head Loss (Porosity)
- Specificity (Formulation)
- Capacity (Chemistry, Surface Area)
- Kinetics (Formulation)
- pH (Solubility)
- Oxidation/Reduction (Species Formation)
- Initial Concentration (Capacity)

Study Methods

- Bench scale column studies
- Geochemical modeling software (PHREEQC).

Sorption

Criteria

Design

- Quantity of Media
- Configuration
- Dimensions
- Flow
- Breakthrough
- Based on preliminary PHREEQC trial runes

Experimental Design

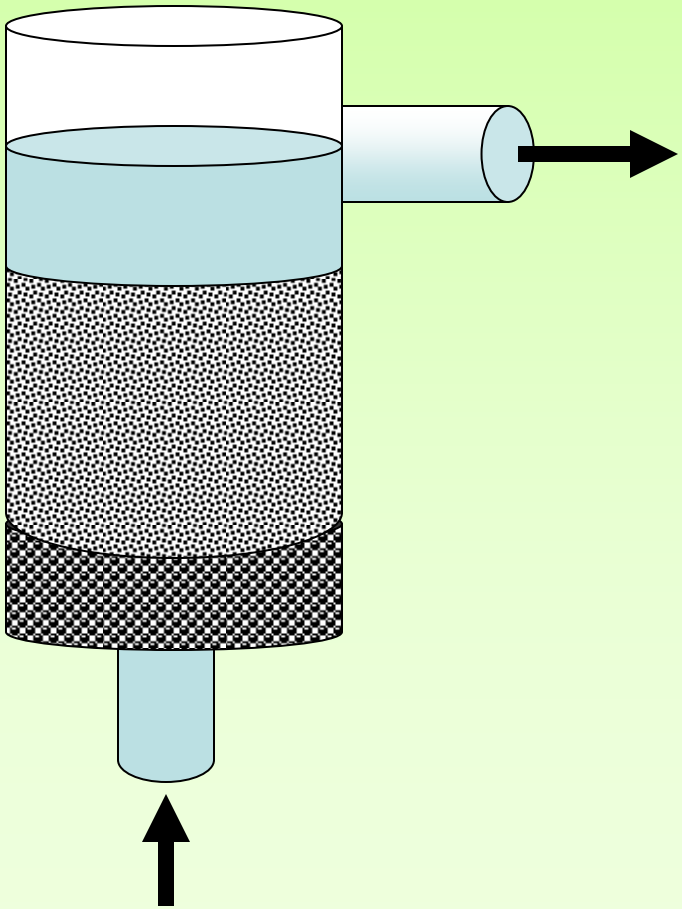
- Columns set up
  - Duplicates with equivalent porosity
  - Conservative tracers used to test dispersivity (clean water, pulse, clean water)
  - Add P solution at levels to not reach super saturation, but to demonstrate sorption reactions
  - Add P solution that is still super saturated with respect to the likely phosphate minerals after sorption loss
  - Sample influent and effluent
  - Add data collected to PHREEQ model, refine testing and model as needed.

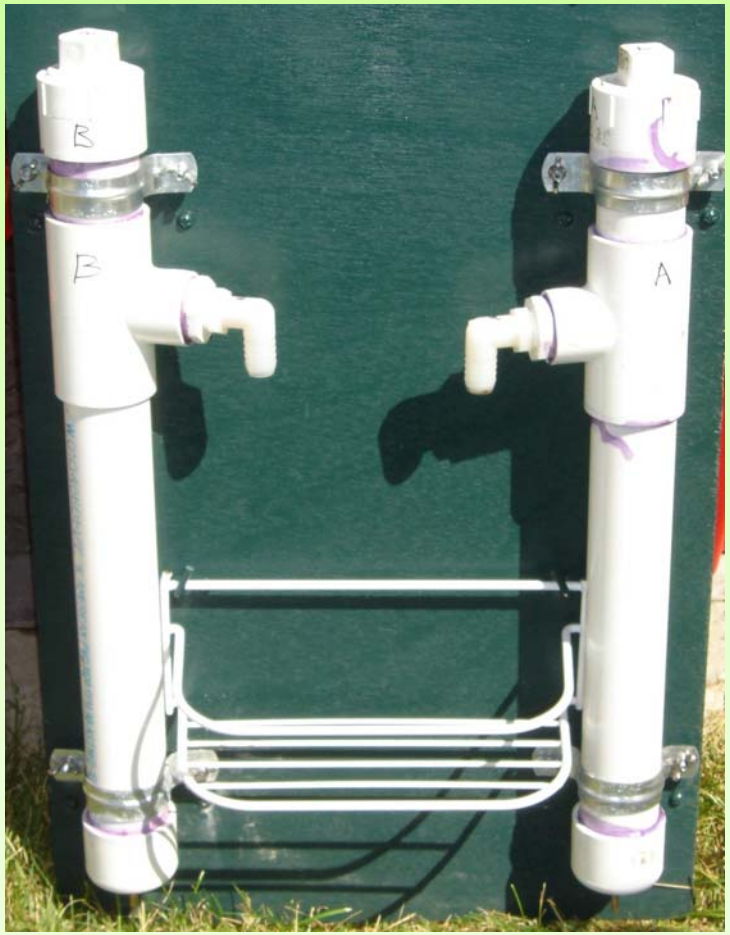
Experimental Design

- Saturated column study
  - ASTM C33 sand chosen as media
    - Commonly specified
    - Represents soil “of concern” around lakeshores
  - To achieved saturation small column length and diameter will be used
  - Run at 3 pHs: low, neutral and high
  - Synthetic wastewater used
  - Average influent phosphorous: 7.5 mg/L P
  - No carbon or microbial interactions evaluated

Experimental Design

Column Design





Experimental Design

Column Design

Data Collection & Analysis in 2008

For More Information

http://septic.umn.edu

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