Phosphorus treatment in onsite septic systems
Why would we do it and what is the present state of the art?

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Phosphorus

• A key “limiting nutrient” in freshwater systems
• When phosphorus enters freshwater ecosystems and nitrogen becomes limiting then harmful algae blooms (HAB) form and present a public health hazard.
• Once phosphorus enters a freshwater ecosystem, it becomes the “gift that keeps on giving”
What’s the big deal about a little algae?
Health Impacts of Cyanotoxins

Note: Not all cyanotoxins lead to all of these health impacts. These listed impacts are caused by microcystins or cylindrospermopsin, the two cyanotoxins that EPA has issued Health Advisories for.

**IN HUMANS**

**Brain**
*Source:* Ingestion
*Symptoms:*
  - Headache
  - Incoherent speech
  - Drowsiness
  - Loss of coordination

**Respiratory System**
*Source:* Inhalation
*Symptoms:*
  - Dry cough
  - Pneumonia
  - Sore throat
  - Shortness of breath
  - Loss of coordination

**Digestive System**
*Source:* Ingestion, drinking contaminated water, or eating contaminated fish
*Symptoms:*
  - Abdominal pain
  - Nausea
  - Vomiting
  - Diarrhea
  - Stomach cramps

**Body**
*Source:* Contact, e.g. swimming
*Symptoms:*
  - Irritation in eyes, nose, and throat
  - Blistering around the mouth
  - Skin rash, including tingling, burning and numbness
  - Fever
  - Muscle aches (from ingestion)
  - Weakness (from ingestion)

**Organs**
*Source:* Ingestion
*Symptoms:*
  - Kidney damage
  - Abnormal kidney function
  - Liver inflammation

**Nervous System**
*Source:* Ingestion
*Symptoms:*
  - Tingling
  - Burning
  - Numbness

**IN PETS**

*Symptoms:*
  - Vomiting
  - Fatigue
  - Shortness of breath
  - Difficulty breathing
  - Coughing
  - Convulsions
  - Liver failure
  - Respiratory paralysis leading to death
Where does phosphorus fit in as a difficulty for treatment?
Challenges for onsite septic system treatment

- Wastewater “Stabilization” (removal of oxygen demand, oxidation of ammonia)
- Nutrient
  - Phosphorus
- Nutrient
  - Nitrogen
- Pathogens (bacteria and viruses)
- Contaminants of emerging concern
- Dispose of volume
Challenges for onsite septic system treatment

Contaminants of emerging concern

Nutrient
Phosphorus

Nutrient Nitrogen

Pathogens (bacteria and viruses)

Wastewater “Stabilization” (removal of oxygen demand, oxidation of ammonia)

Dispose of volume

Increasing difficulty

'??
What is the state of the art?

• Two technologies with Pilot Approval in the Commonwealth
• At least two additional technologies available but that have not sought approval
• Two soil absorption system techniques that can attenuate phosphorus are available
• One diversion technique is approved but not generally accepted
Systems with Pilot Approval
“RID” stands for Reactive Iron Dissolution – Iron is combined with phosphorus to make insoluble compounds to immobilize the phosphorus. “Sacrificial” media needs to be replaced at some point.
The PhosRID ™ unit

- concrete tank filled with iron-rich porous media
- iron solids in the media are designed to react with the carbon and phosphate to form solids such as vivianite and strengite
- \( \text{CH}_2\text{O} + 4\text{Fe(OH)}_3 + 7\text{H}^+ \rightarrow 4\text{Fe}^{2+} + \text{HCO}_3^- + 10\text{H}_2\text{O} \)
- \( 3\text{Fe}^{2+} + 2\text{PO}_4^{3-} + 8\text{H}_2\text{O} \rightarrow \text{Fe}_3(\text{PO}_4)_2 \cdot 8\text{H}_2\text{O} \) (vivianite)
- \( \text{Fe}^3^+ + \text{PO}_4^{3-} + 2\text{H}_2\text{O} \rightarrow \text{Fe}_3(\text{PO}_4)_2 \cdot 2\text{H}_2\text{O} \) (strengite)
The PhosRID™ unit

Total Phosphorus
Mean 5.2 mg/l
Median 5.2 mg/l

Iron Dissolution
(solubilized iron combines with phosphate)

Soluble iron compounds containing phosphorus precipitate on sand filter

Remaining iron-phosphorus compounds precipitate on sand as strengite

Septic Tank

Influent
Mean 5.7 mg/l
Median 5.7 mg/l

Total Phosphorus
Mean 3.9 mg/l
Median 4.1 mg/l

Total Phosphorus
Mean 0.2 mg/l
Median 0.3 mg/l
Source: http://www.lombardoassociates.com/pdfs/phos-rid.pdf

### Site #1
- Address: 56 Meadow View Drive
- PhosRID™ System Effluent (mg/l):
  - Date: 07/05/07, Flow: 139.9, TP: 1.30, BOD: <0.02, TSS: <0.02
  - Date: 08/05/07, Flow: 144.9, TP: 4.10, BOD: 0.08
  - Date: 09/11/07, Flow: 35.2, TP: 0.04, BOD: <0.02, TSS: <0.02
  - Date: 12/17/07, Flow: 17.7, TP: 6.30, BOD: <0.02, TSS: <0.02
- Site #2
- Address: 11 Columbus Ave
- PhosRID™ System Effluent (mg/l):
  - Date: 03/25/08, Flow: 1.6, TP: 9.50, BOD: 0.03, TSS: <0.02
- Site #3
- Address: 76 Millbrook

### Environmental Engineers/Consultants
Lombardo Associates, Inc.
188 Church Street
Newton, Massachusetts 02458
www.LombardoAssociates.com
Tel: 617-964-2924
Fax: 617-332-5477

PhosRID™

### Percent P Removal
- Site #1: 98.6%
- Site #2: 99.1%
- Site #3: 99.3%
Natural iron electrodes are dissolved into the sewage stream as ferrous ions, where they react with phosphorus to form insoluble P-based minerals downstream of the electrodes.
The technology is abiotic, thus temperature independent, consumes ~0.5 kW-hr per day per residence, is largely independent of water characteristics, has no sludge or reactive medium issues, and has no adverse effect on pH.
ADVANCES IN PHOSPHORUS REMOVAL IN SEPTIC SYSTEMS
Craig Jowett, Lingling Wu, Jianhui Sun, Christopher James
PAPER PRESENTED AT NOPWRA CONFERENCE 2014
One Installation in Brewster to begin testing Spring 2019
Ways to encourage the natural processes?

*Use the B soil horizon to situate disposal means*
Soil – Doing what comes naturally

A Horizon

• Soil organic matter degrades to form CO2 and carbonic acid ($H_2CO_3 = H^+ + HCO_3^-$)
• Protons ($H^+$) help break down Fe-rich silicate minerals, releasing ferrous ions ($Fe^{2+}$) into solution.
• Microorganisms reduce $Fe^{3+}$ to $Fe^{2+}$, mobilizing Fe until it encounters an area suitable for precipitation.
• In the oxidizing B-horizon soil, ferrous iron converts to ferric iron ($Fe^{3+}$), which readily precipitates as the characteristically colored yellow, red, and brown hydroxides.

B Horizon

- The dissolved iron percolates downwards and precipitates, primarily as oxidized ferric iron oxides and hydroxides, where it becomes part of the underlying B-horizon mineral matrix
- Reactive phosphorus dissolved in water passing through the B-horizon soil binds chemically to iron oxides to ultimately form iron-phosphate minerals
- Stable, insoluble Fe-P minerals form in both oxic and anoxic conditions, e.g., as strengite [FePO\(_4\)·2H\(_2\)O] in oxidizing, ferric (Fe\(^{3+}\)) conditions, and as vivianite in reducing, ferrous (Fe\(^{2+}\)) conditions. Strengite has a solubility product constant Ksp = 10\(^{-22}\) and vivianite has a Ksp = 10\(^{-36}\).
Advantages to soil-based phosphorus removal

• It’s passive
• Maintains phosphorus in an area where it can be recycled into the soil biomass

Disadvantages to soil-based phosphorus removal

• It is finite in its capacity
• At some point the exhausted soil only passes the phosphorus downstream.
Shallow soils-based systems that integrate wastewater disposal and treatment by optimizing natural processes are also effective at attenuating phosphorus.
Technologies not yet approved
In the Commonwealth of Massachusetts
• Passive unit following septic tank or treatment unit
• Uses gravity dispersal over an adsorptive media layer
Total Phosphorus Levels

- 97.9% Phosphorus Removal
- 92.4% Phosphorus Removal

Phos-4-Fade® Filter Effluent

- After Hydro-Kinetic Treatment System: 0.15 mg/L
- After Septic Tank 6 Months Data: 0.44 mg/L
- BNQ Standards: 1 mg/L

norweco®
PHOS-4-FADE®
PHOSPHORUS REMOVAL FILTER
DpEC Self-Cleaning Phosphorus Removal Unit
The Electro-Coagulation (EC) Principle

- Principle of EC: low intensity electric current (DC) applied between 2 submerged electrodes.

- PO$_4^{3-}$ is removed from wastewater by allowing it to react with Al$^{3+}$ cation, which will precipitate under the form of AlPO$_4$. 
System Description

- Phosphorus removal unit using electro-coagulation (EC)  
  (Patent pending in Canada, United States and Europe)

- Unit treating up to 2,200 L/d (580 gallons)
- Unit volume of 2,000 liters (528 gallons)

TSS: 30-40 mg/L  
BOD₅: 50-60 mg/L  
Ptot: < 0.8 mg/L
Certification Results

- CAN/BNQ results: Primary Reactor + EC Unit

<table>
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<th>Parameters</th>
<th>IPR</th>
<th>ECE(^1)</th>
<th>Removal</th>
<th>Classification</th>
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<tbody>
<tr>
<td>TSS (mg/L)</td>
<td>231 ± 65</td>
<td>33 ± 23</td>
<td>86%</td>
<td>BI</td>
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<tr>
<td>CBOD(_5) (mg/L)</td>
<td>188 ± 63</td>
<td>53 ± 23</td>
<td>72%</td>
<td>BI</td>
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<td>P total (mg/L)</td>
<td>5.1 ± 1.7</td>
<td>0.4 ± 0.4</td>
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<td>FC (log)</td>
<td>6.4 (2,272,815)</td>
<td>4.8 (62,773)</td>
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\(^1\) ECE: Electro-coagulation Unit Effluent
Life Span

- Electrodes lifespan: 3,930 h
Finally

Lest we forget....
Questions?