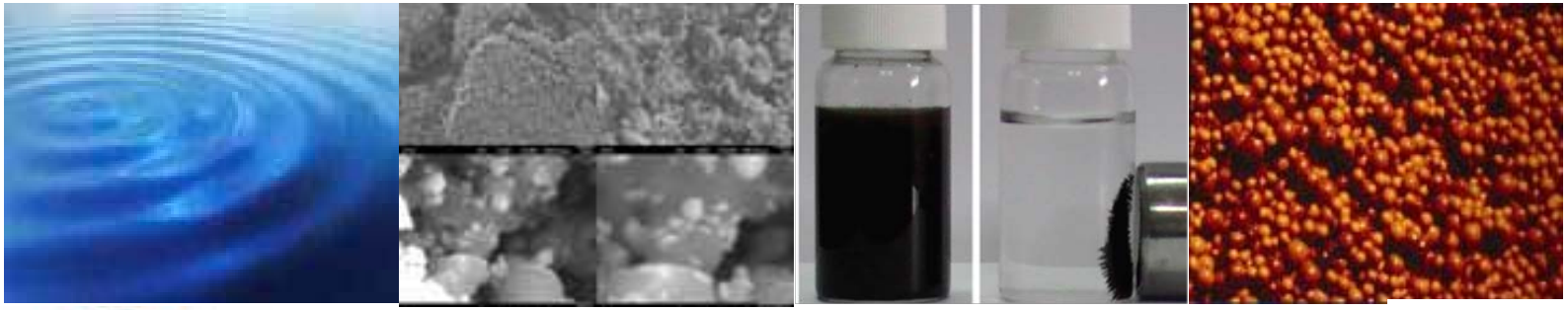
Sustainable Point and Non-Point Source Nutrient Pollutant Phosphorus Control Using Nanotechnology

By: Edward Weinberg, P.E., President



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Defining Nanotechnology

- **Nanotechnology:** n - A wide range of technologies that measure, manipulate, or incorporate materials and/or features with at least one dimension approximately <100 nanometers (nm). Such applications exploit nanoscale properties, distinct from those of the bulk or macro counterparts.

  Materials **are central in nanotechnology**

  Critical and defining dimension **~1 – 100nm**

  Really bizarre and unusual **properties**

- **Nanotechnology involves stuff that is really small and different**

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P-Removal/Recovery Summary

- Enhanced Biological Phosphorus Removal
- Chemically Enhanced Phosphorus Removal
- **Ion Exchange (REM-NUT, Asahi Kasei IX) & Recovery**
- **Selective Media & Recovery**
- **Adsorptive <u>Nano Iron Oxide</u>: Layne RT IX & Recovery**
- **<u>Nanocomposites</u>: Novel, Synanomet & Recovery**

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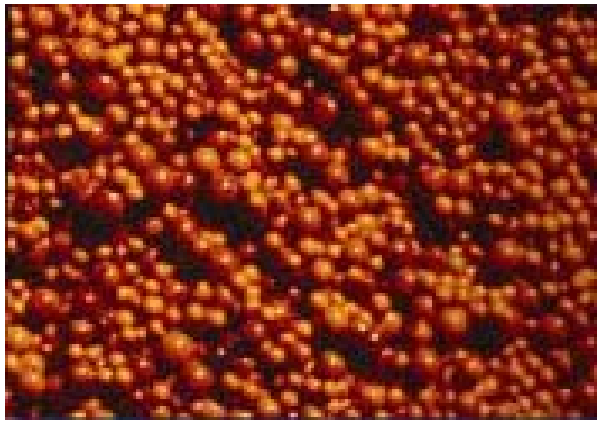
P-Recovery Ion Exchange Chemistry

PHOTOGRAPH LAYNE RT IX RESIN



$$2R\text{-}Cl + HPO_4^{=} \;===\; R_2\text{-}HPO_4 + 2Cl^-$$

Where R = anion exchanger

Regenerated with NaOH

$$Z\text{-}Na + NH_4^+ (K^+) \;===\; Z\text{-}NH_4 (K^+) + Na^+$$

Where Z = Zeolite

Regenerated with NaCl & NaOH

When cation and anion regeneration solutions are properly mixed, and a soluble Mg salt (e.g., $MgCl_2$) is added, the result yields a virtually non-toxic, sterile struvite-rich precipitate according to:

$$Mg^{2+} + NH_4^+ (K^+) + HPO_4^{=} \;===\; MgNH_4(K^+)PO_4 (s) + H^+$$

where (s) = Struvite

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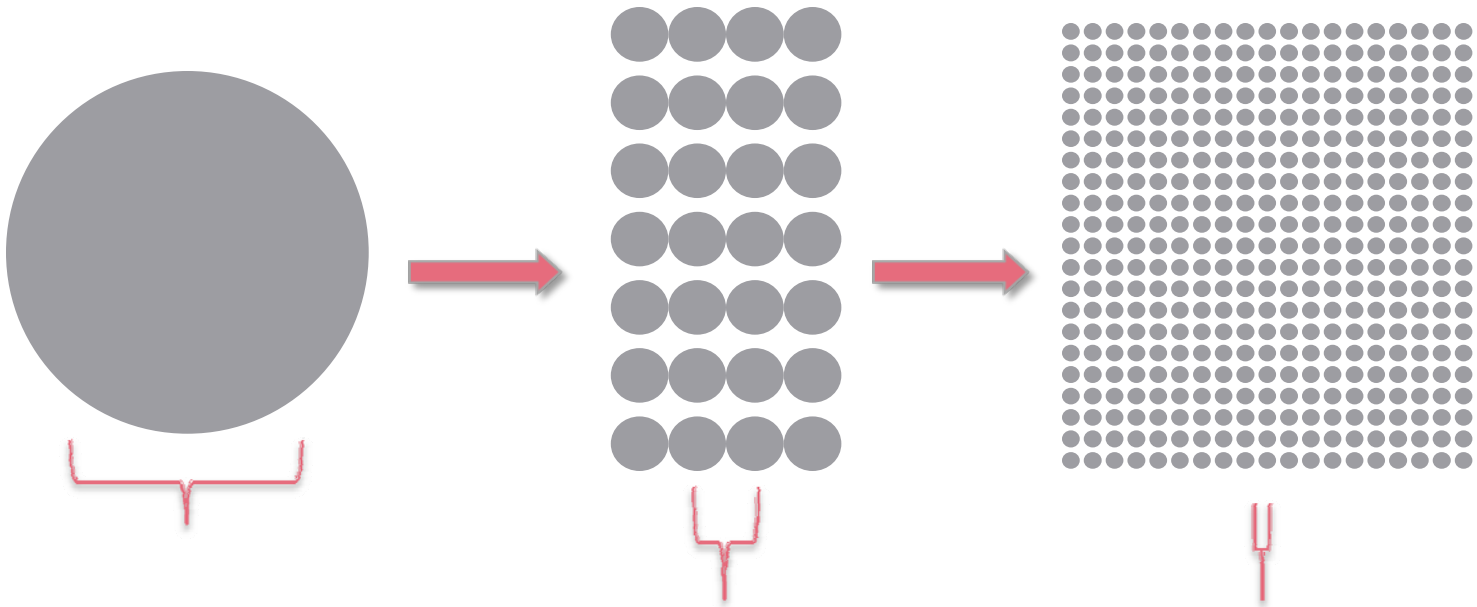
Nanotechnology: Small Stuff, Huge Surface

- One milligram of quartz sand



100 Micron	1 Micron	10 nm
9 Square cm	3 Square Meters	300 Square Meters
One Hundred Particles	One Billion Particles	One Hundred Trillion Particles

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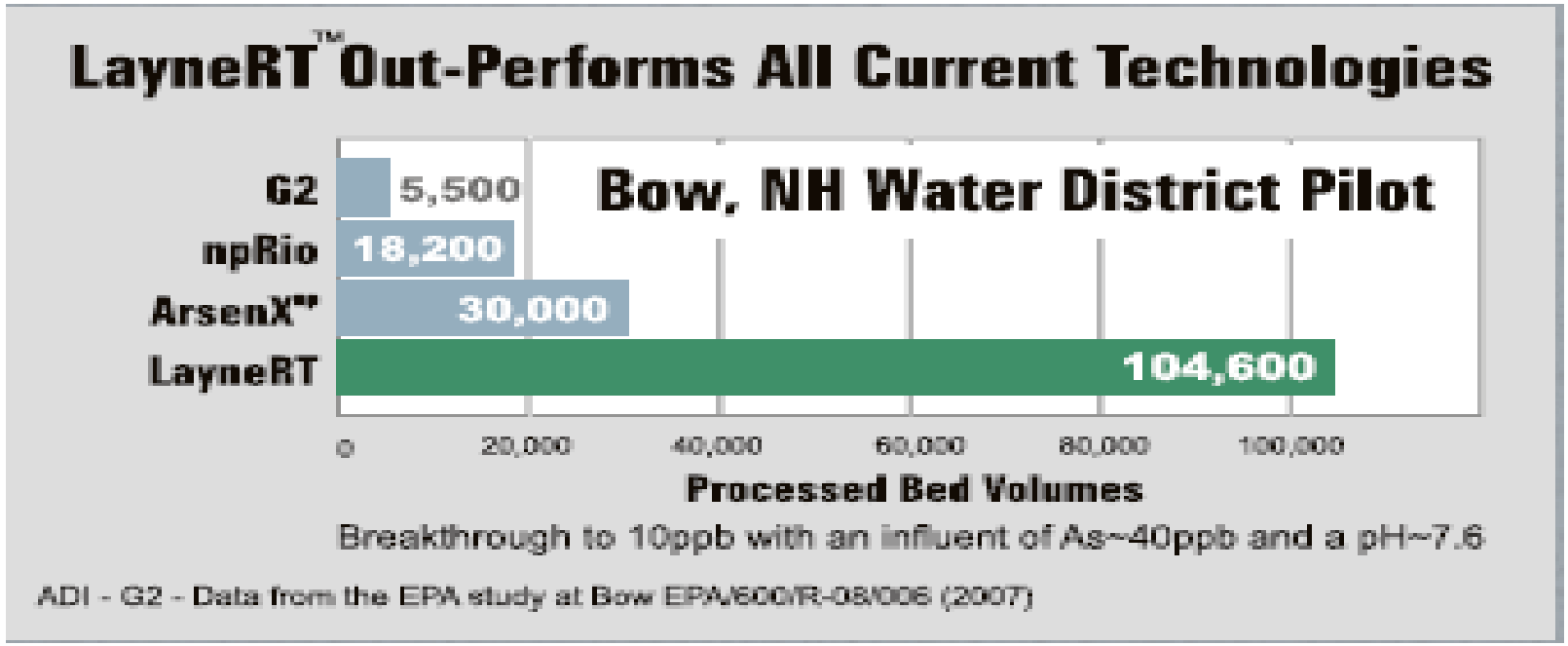
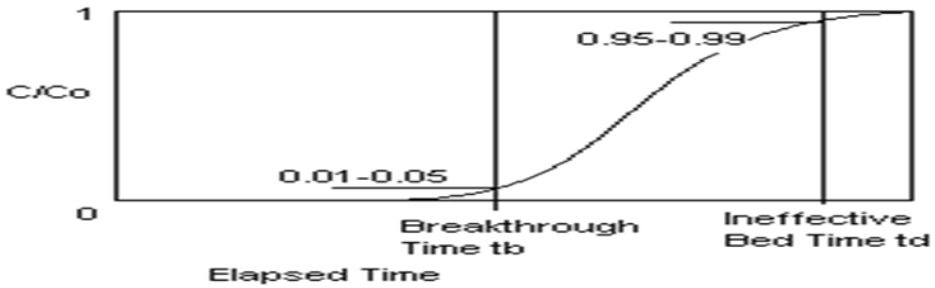
The Power of Nano-Based Media





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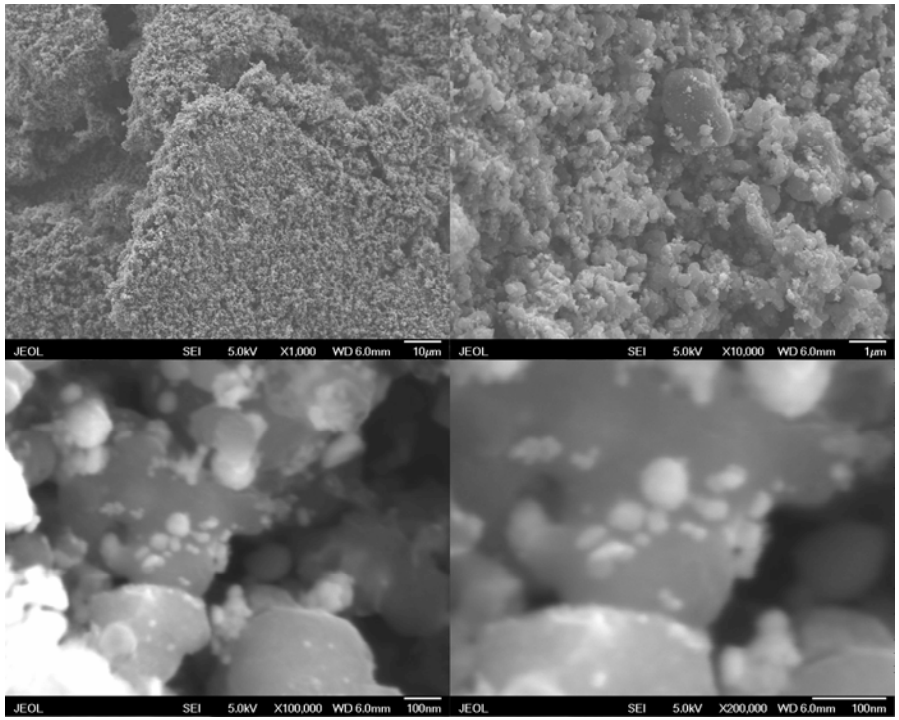
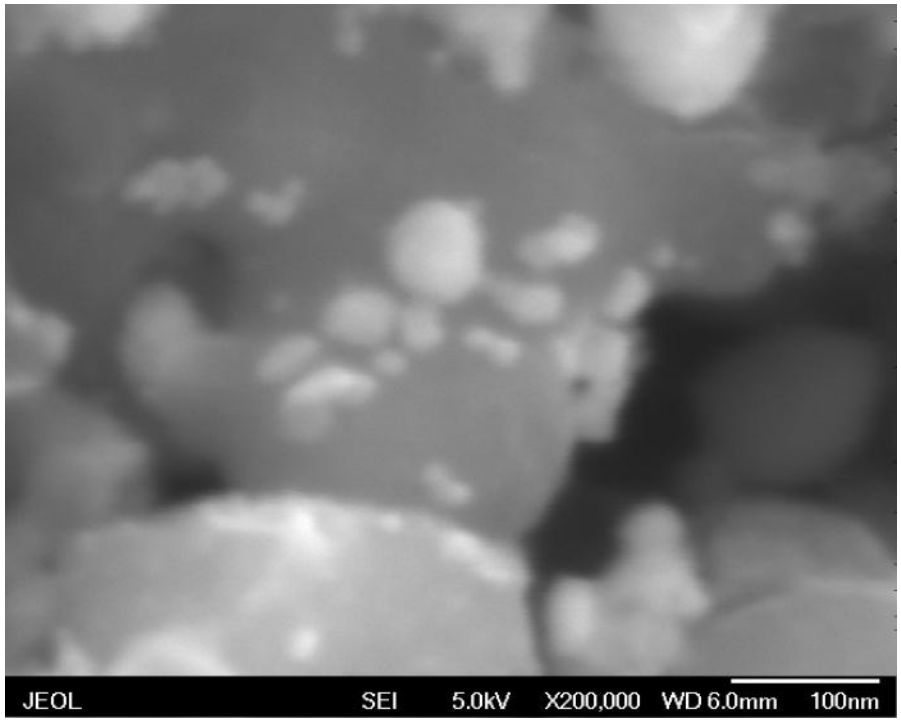
NanoComposites – Syanomet/UALR



GG1-43-2B (C-Ni, solution method),

BET surface area: approx. 400 m^2/g



GG1-59-4 (C-Ni, powder method),

BET surface area: approx. 425 m^2/g

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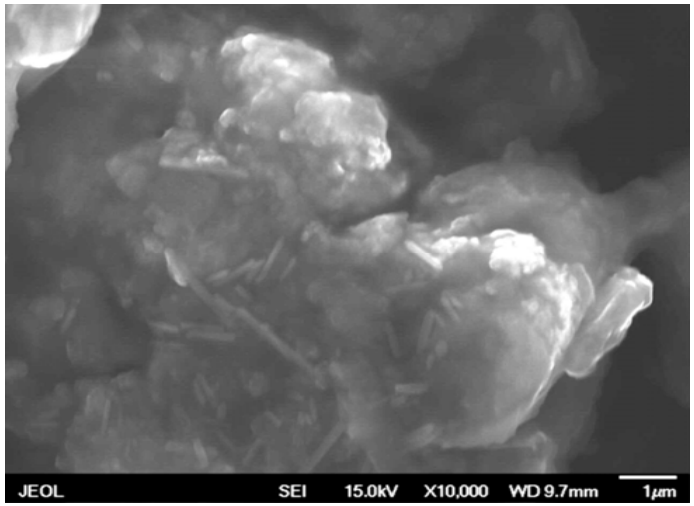
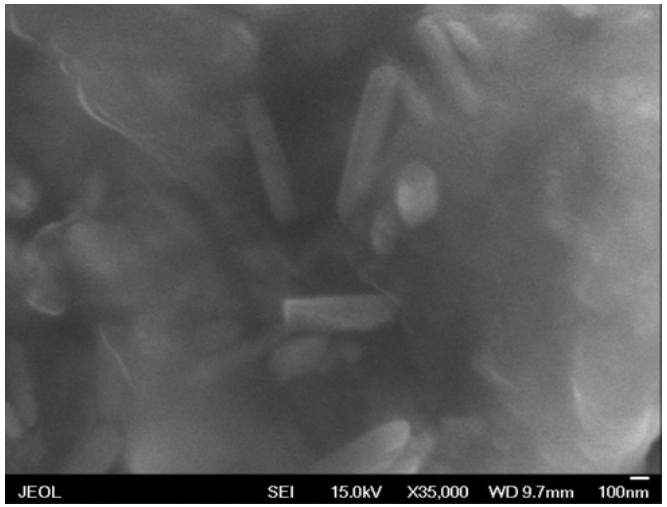
NanoComposites – Syanomet/UALR





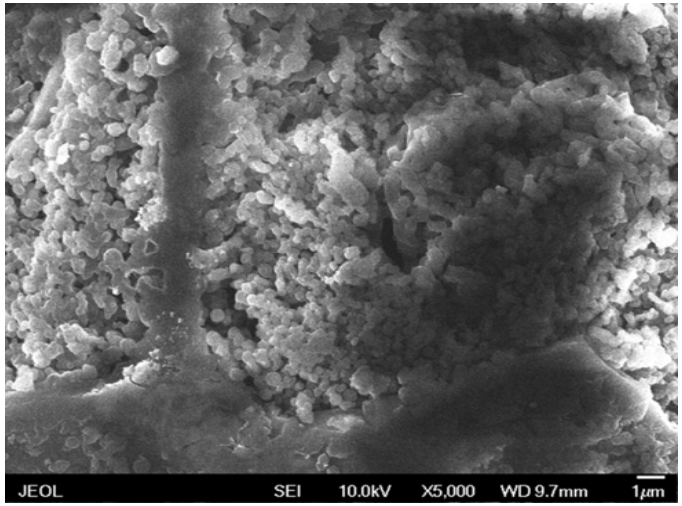


Image A.

Wood-based magnetite composite prepared using NaCl as a spacer.

Image B.

Enlarged area of image A. Showing various lengths of magnetite particles (200nm to 700nm)

Image C.

Quarternized Wood-based magnetite composite.

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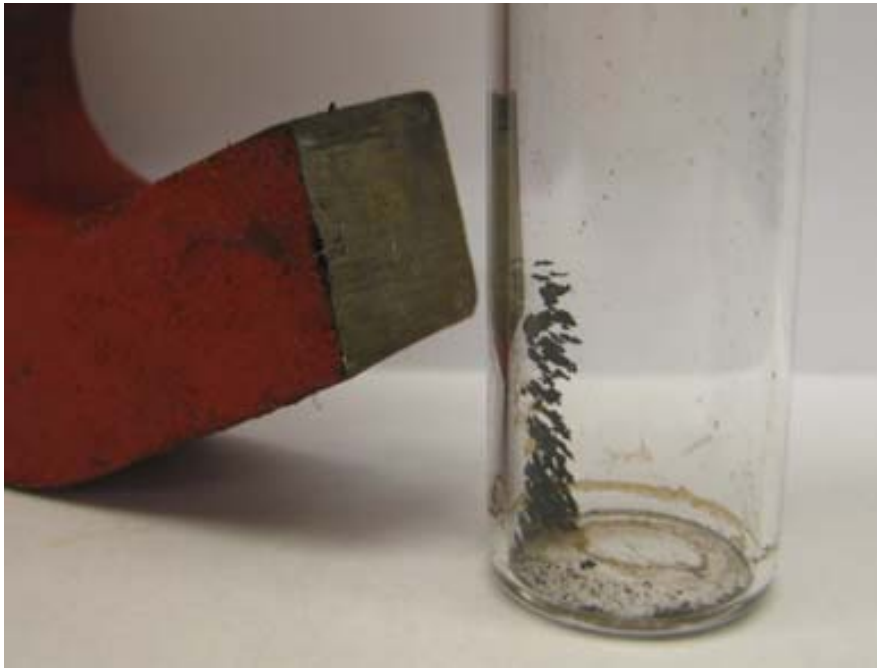
Magnetic Separation of Synanomet Nanocomposite in Solution



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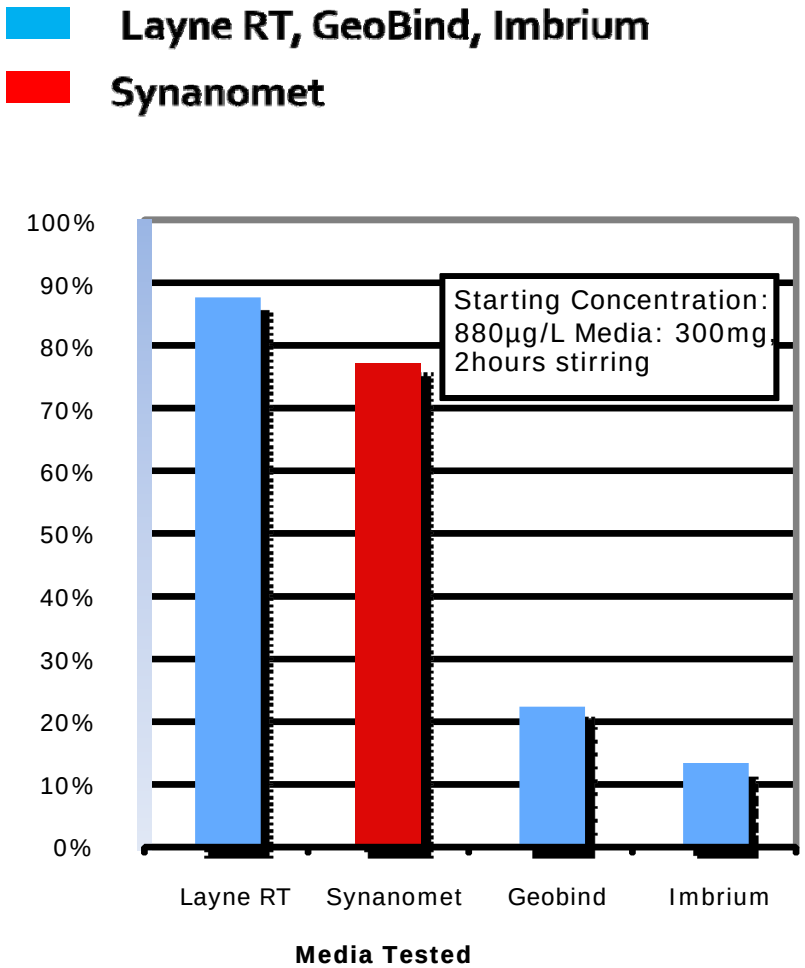
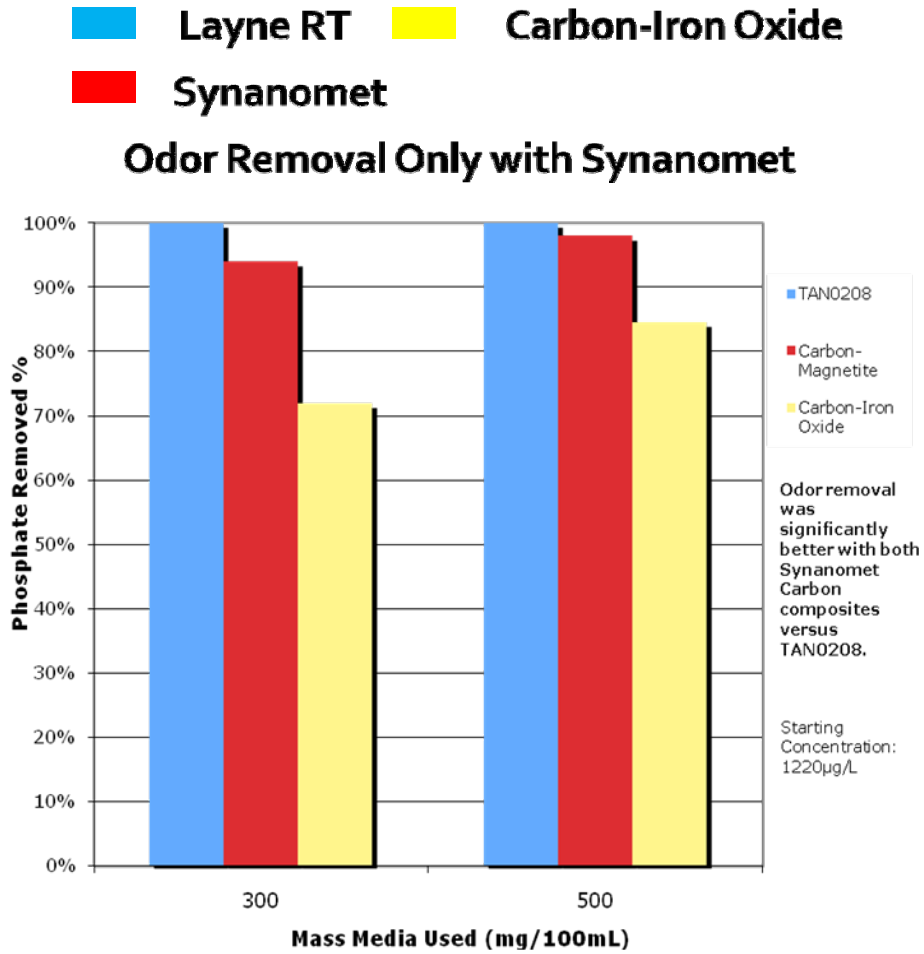
Phosphate removal effectiveness comparison of Synanomet's nanocomposite and Layne RT





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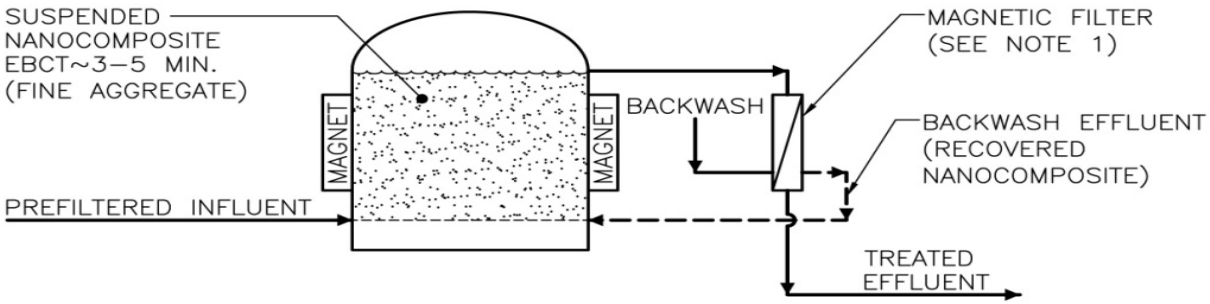
Nano-Media Filter Column Configurations

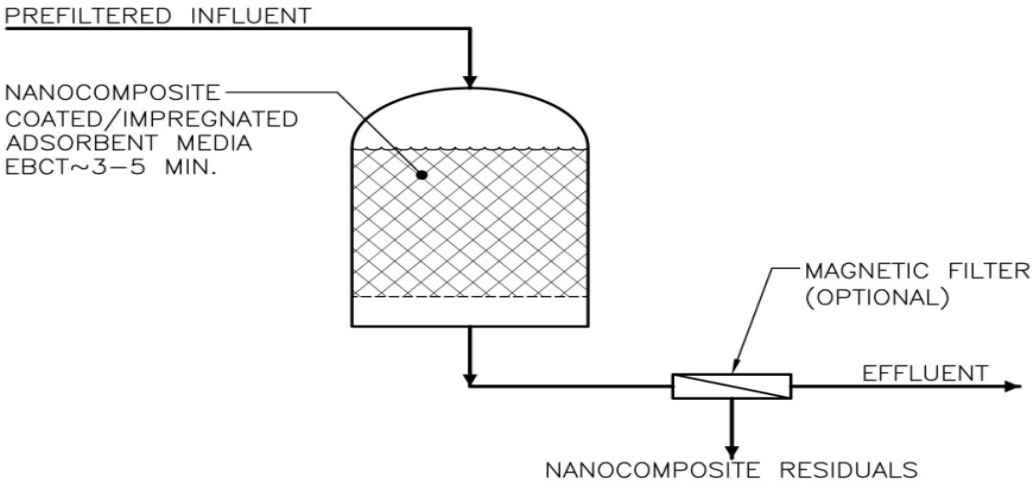


NOTE 1

MAGNETIC FILTER FOR RECOVERY SHOWN EXTERNAL TO VESSEL. MAY ALSO BE INSTALLED INTERNAL TO THE THE VESSEL.

UPFLOW, SUSPENDED BED "AS IS" NANOCOMPOSITE ADSORBER VESSEL

NOT TO SCALE



NOTE:

DUAL ADSORBER VESSEL (NOT SHOWN) FOR CONTINUOUS FEED FORWARD DURING VESSEL REGENERATION. OPTIONAL FILTER COMMON TO BOTH VESSEL DISCHARGES.

CONVENTIONAL, DOWNFLOW NANOCOMPOSITE IMPREGNATED ADSORBER VESSEL

NOT TO SCALE

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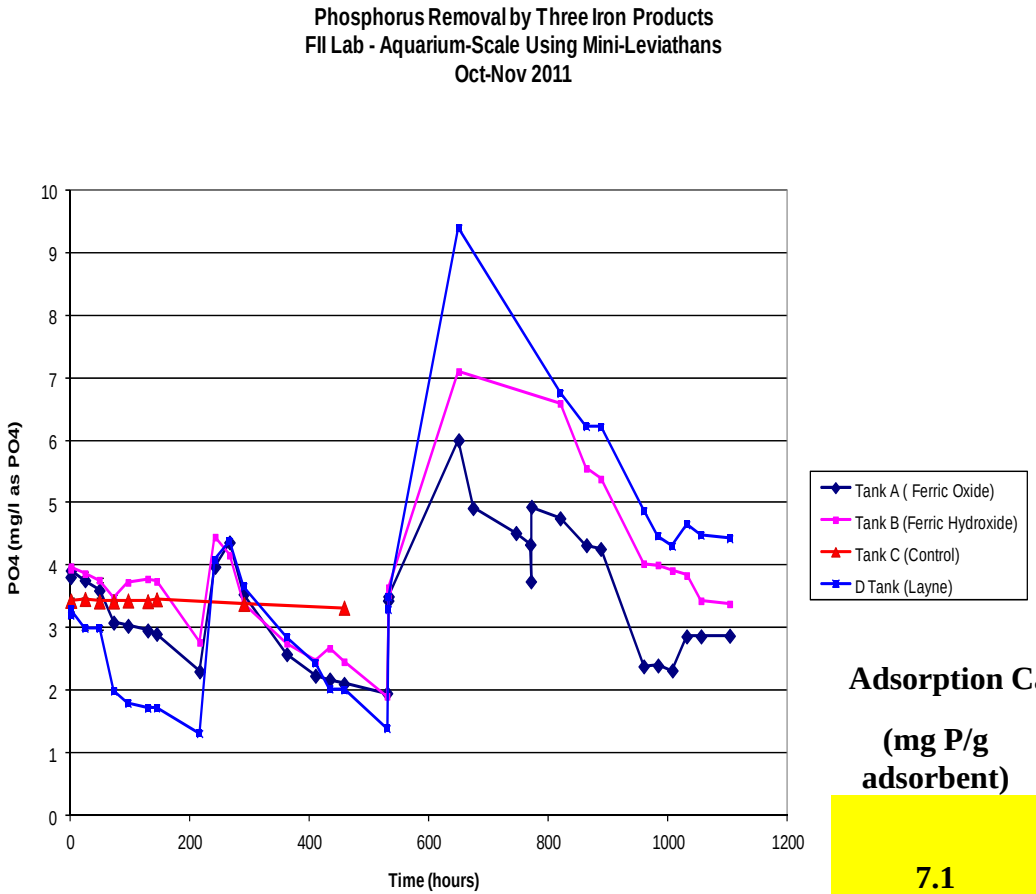
Comparative P Removal - Runoff Waters



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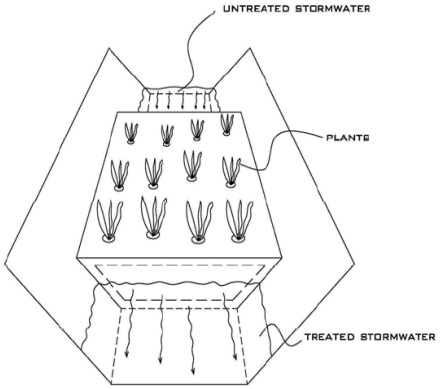
Adsorption Capacity

(mg P/g adsorbent)	Media
7.1	Iron Oxide
6.3	Ferri Hydroxide
8.4	**Layne RT**



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Factors : Nanotechnology Economic Analysis WWTP P-Recovery

- Municipal – High Flow, Low Concentration
- Industrial – Lower Flows, Higher Concentrations
- Regenerable – Reusable By-product Fertilizer (P) Solutions
- No Sludge – Alum or $FeCl_3$ replacement
- Variable P influent – Non-Detect (initially) DP effluent (Nutrient Trading Credit generation)
- Prefiltering required & adaptable to non-point source apps

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Nutrient Removal & Recovery ENR&R - Approach Benefits

- **Improve water quality** - *Cleaner water for reuse or discharge*
- **Reduce pollutant loading to Chesapeake Bay Watershed**
- **Recover nutrients** - *Sustainability, recycle finite resource P*
- **Generate new revenue streams**

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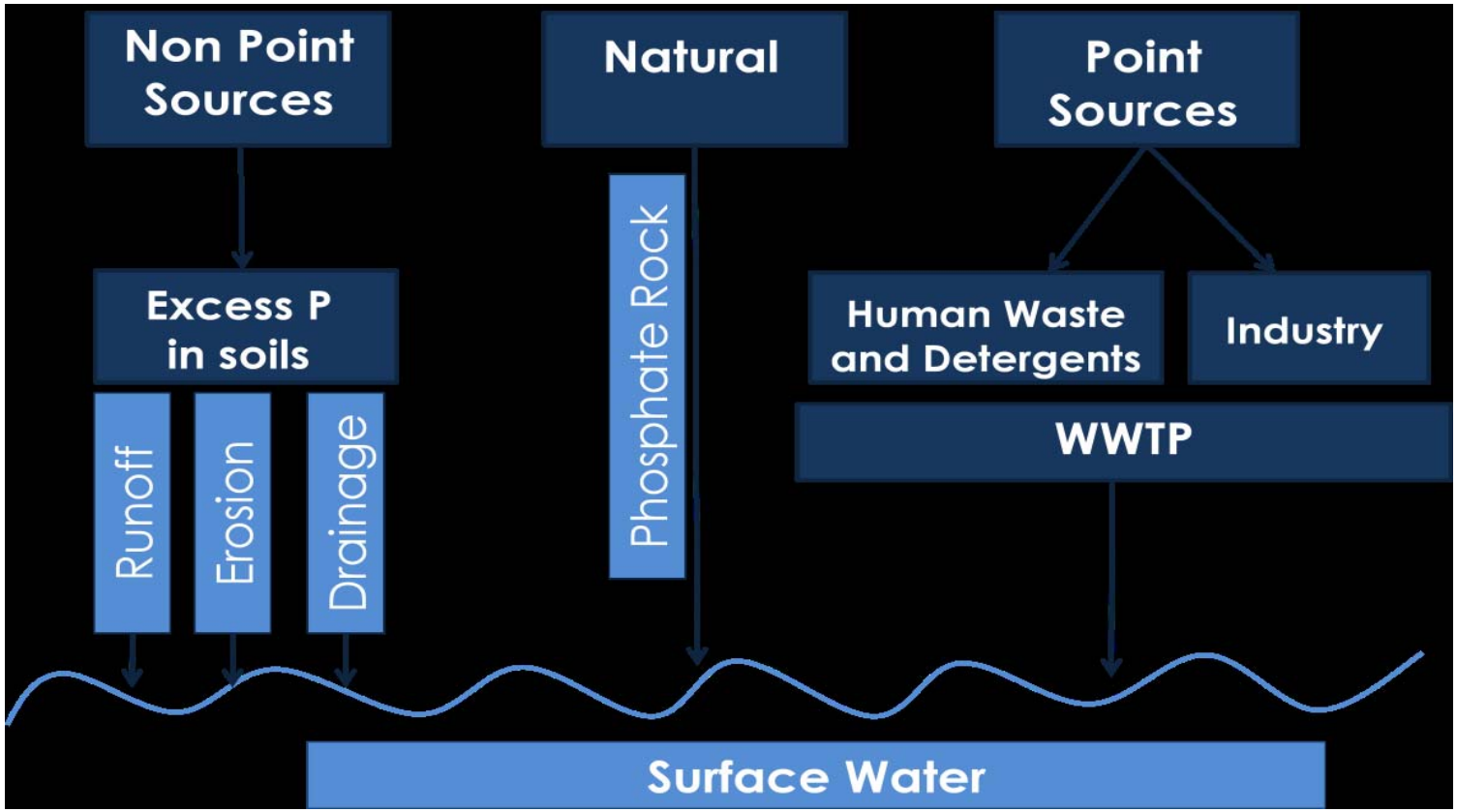
Phosphorus source pathways to surface water are also "sinks" for recovered P

Urban & Ag Runoff

Phosphate Fertilizer

Municipal & Industrial



Adapted from Wind, 2007

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RD&D Plans - Nano Based ENR&R

- Microcolumn studies for Synanomet nanocomposites
- Odor control investigation (Synanomet)
- Additional nanotechnology RD&D for oxyanion water purification markets (Arsenic, Selenium, Perchlorate)

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Business Plan - Nano Based ENR&R

- Layne RT ion exchange resin commercially available now for Phosphorus removal and recovery – Field Pilot Tests
- Off-Site IX Regeneration Centers business model
- "Nutrient mining" pt.-source muni and industrial WWTPs, Landfill Leachate, CAFO/AFO Digesters and aquaculture

- Non-pt. Source: Green Infrastructure, Watershed Runoff – Field Pilot Demonstrations

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QUESTIONS

The Best Things Come in Small Packages" - Proverb