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BIODEGRADABLE BEADS FOR CAPTURING PHOSPHORUS FROM WATER AND RELEASING IT AS FERTILIZER

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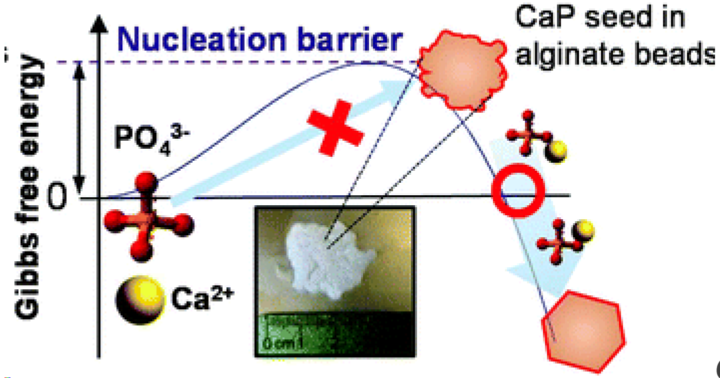
Engineers in Prof. Young-Shin Jun's laboratory at Washington University in St. Louis have developed a scalable, effective, environmentally-friendly system for removing phosphorus from water using biodegradable alginate beads that can then be recycled as a slow release fertilizer in soil. This technology is designed to solve two problems: capturing excess phosphorus to improve water quality and protect local aquatic systems; and providing a sustainable alternative to mining as a source for phosphorous fertilizer. This is achieved using a calcium phosphate (CaP) seed as a nucleation site for particle growth. These seeds within the benign alginate beads are engineered with crystalline properties to extract excess phosphorus from the surrounding environment at ambient temperature and neutral pH. The effective phosphorous extracting ability of the seed at neutral pH eliminates the necessity of pH adjustment after the process. After phosphorus collection, the macroscale beads maintain their solid structure and can be easily removed from the water using mesh or nets, without additional filtration or centrifugation. Finally, when the beads are placed in phosphate-deficient soil, the phosphorus is slowly released as fertilizer. This phosphorus remediation and recycling system could provide a 'green' approach to manage the global phosphorus cycle to secure, food, energy and water for a growing population.



Green chemistry to manage the phosphate cycle: *The composite material of alginate beads seeded with CaP overcomes energy barriers to enhance mineral nucleation in solution. The CaP seed crystallization can be engineered to govern the equilibrium phosphorus concentration during the removal and release processes.*

Stage of Research

The inventors have performed proof-of-principle experiments, demonstrating:

- crystalline control calcium phosphate seed minerals at room temperature without using hazardous substances or energy input

- alginate beads calcium phosphate seeds effectively decreased aqueous phosphorus concentration from 200 to 22.7 mM (~90%) within one day at a final pH of 7.2
- recovered phosphorus can be reused as a slow-release fertilizer in a phosphorus-deficient environment

Applications

- **Remediation –** remove phosphorus pollution from both natural and engineered water sources to prevent mass die offs due to eutrophication in local aquatic systems
- **Fertilizer** – phosphorous extracted from the water can be recycled as a slow-release fertilizer, providing an alternative to phosphorous mining

Key Advantages

- **Scalable in situ process:**
  - beads continuously remove phosphorus by incorporating material from the environment
  - phosphorus can be extracted directly from the water and does not require a centralized treatment facility
- **Environmentally-friendly, sustainable synthesis and phosphorous recycling**
  - simple nucleation process for generating beads allows control of crystalline structure without hazardous substances or additional energy input
  - raw materials (calcium, phosphate and alginate) are abundant in nature and are environmentally benign
  - beads remove phosphorus from water at room temperature and neutral pH (no additional pH adjustment needed after treatment)
  - alginate beads are biodegradable in soil when used as fertilizer
  - beads selectively remove phosphorus in the presence of arsenic (excluding arsenic provides environmental safety as a fertilizer)
- **Slow-release fertilizer:**
  - solubility of beads can be engineered to slowly release phosphorous in phosphate-deficient areas
  - hydrogel phase of the beads are expected to provide additional benefit by strongly hold water and nutrients in soil, thus it will be especially useful for an arid area
- **Convenient recovery:**
  - beads retain phosphorus even if water chemistry, such as ionic strength (salinity) and pH, changes
  - stable, macroscale beads can be easily collected from treated water using mesh or nets, without additional filtering or centrifugation steps

Publications

- Kim, D., Wu, T., Cohen, M., Jeon, I., & Jun, Y. S. (2018). Designing the crystalline structure of calcium phosphate seed minerals in organic templates for sustainable phosphorus management. *Green Chemistry*, 20(2), 534-543.

Patents

- Provisional U.S. patent application filed

Website

- Jun Lab