

Executive Summary

- This study investigates the removal of phosphorus (P) from wastewater using biosolid beads made from sodium alginate, magnesium hydroxide, and biosolids.
- The effects of alginate concentration, $Mg(OH)_2$ loading, and biosolid content were evaluated to determine the phosphorus removal performance.
- Results indicated that bead composition significantly influences treatment efficiency, with optimal performance achieved at low alginate and biosolid contents combined with moderate $Mg(OH)_2$ concentration.
- These findings support the feasibility of using biosolids for phosphorus capture and potential reuse as an agricultural fertilizer.

Background

Definitions

- Biosolids (Sludge):** organic solids from wastewater treatment that are rich in nutrients.
- Phosphorus (P):** nutrient needed for growth but harmful in excess.
- Struvite ($MgNH_4PO_4 \cdot 6H_2O$):** solid crystal formed from magnesium ammonium phosphate under alkaline precipitation conditions.

Why Phosphorus Recovery & Reuse?

- Excess phosphorus in the environment leads to eutrophication [1].
- Biosolids already have high phosphorus content [1].

Why Use Biosolid Beads to Recovery Phosphorus?

- Sustainable
- Economical

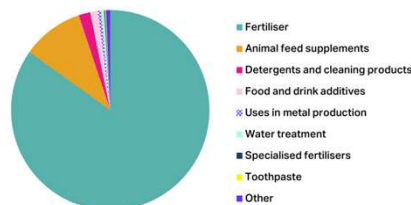


Figure 1. Distribution use of mined phosphorus from phosphate rock [2].

How do Biosolid Beads Capture Phosphorus?

- Magnesium reacts with ammonium and phosphate to form struvite crystals.
- Alkaline conditions (higher pH) increase struvite formation and phosphorus removal.
- Biosolids provide surfaces that adsorb and hold phosphorus.

Experimental Setup

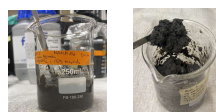
Biosolid Bead Production

- Mix Sodium Alginate & $Mg(OH)_2$



Figure 2. After fully mixing the alginate, the $Mg(OH)_2$ is added and mixed overnight.

- Add and mix powdered biosolids. Pour the final mixture into a syringe.



Figures 3. Final mixtures of biosolid beads.

- Form and drop the final mixture into a $CaCl_2$ bath. Allow cross-linking for 90 minutes.

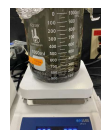


Figure 4. Biosolid beads are gently stirred in a 4 g/L $CaCl_2$ solution, if needed.

- Briefly rinse and pour biosolid beads in a $MgSO_4$ solution.



Figure 5. Biosolid beads in a 5 g/L $MgSO_4$ solution.

- Dry biosolid beads overnight (16 hours).



Figure 6. Biosolid beads before drying.



Figure 7. Biosolid beads after drying.

Experimental Test Plan

Six biosolid beads with different content levels of Alginate ($(C_6H_7O_2Na)_n$), $Mg(OH)_2$, and Biosolids, were prepared to evaluate their effects on P recovery.

Table 1. Parameters for analysis

Run	Alginate (g)	$Mg(OH)_2$ (g)	Biosolids (g)	Water (g)
1	2	5	15	78
2	2	10	15	73
3	3	5	15	77
4	3	10	15	72
5	2	7.5	10	80.5
6	2	7.5	20	70.5

P measurement:

- Phosphorus concentration as $mg PO_4^{3-}/L$ was determined using acid persulfate digestion [3], followed by reactive phosphorus measurement [4].
- Using digestion first converts all phosphorus forms into reactive phosphate, allowing phosphorus to be measured.
- Initial PO_4^{3-} concentration and pH in water: 460 mg/L and 8.

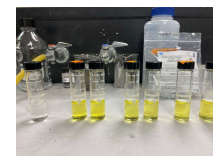


Figure 8. Determining the PO_4^{3-} concentration in the treated water samples.

Experimental Results

Table 2. PO_4^{3-} concentrations in treated water and removal rates

Run	P in treated water (mg/L)	P removal rate (%)	pH in treated water
1	38.75	91.58	8.05
2	40.9	91.11	8.3
3	43.05	90.64	8.25
4	34.5	92.50	8.45
5	28.25	93.86	8.6
6	31.4	93.17	8.35

Run 5 exhibited the highest P removal rate and the compositions is:

- Low alginate (2 wt%)
- Moderate $Mg(OH)_2$ (7.5 wt%)
- Low biosolids (10 wt%)

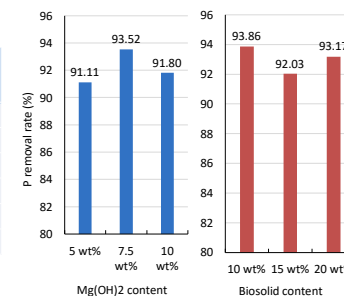
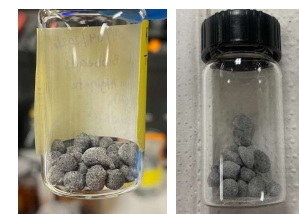


Figure 10. Effect of $Mg(OH)_2$ and biosolid contents on P removal.

Figure 10 shows that,

- Phosphorus removal rate did not further increase at high $Mg(OH)_2$ level.
- Increasing biosolid content did not help improve phosphorus rate.



Figures 9. Biosolid beads after treatment. Struvite is visible as a white cast around the beads.

Summary of Results

- $Mg(OH)_2$ promotes struvite precipitation at low to moderate levels, improving P removal efficiency.
- Excess biosolids hinder performance, likely due to limiting reactive surface area on the beads.

Conclusions

- Biosolid bead composition significantly affects P removal performance, with Run 5 having the highest P removal efficiency and the highest pH after treatment.
- Optimal compositions were identified at:
 - Low alginate (2 wt%)
 - Moderate $Mg(OH)_2$ (7.5 wt%)
 - Low biosolids (10 wt%)
- $Mg(OH)_2$ content has a significant effect on phosphorus removal.
- Biosolid beads show strong potential for sustainable P recovery and reuse as a fertilizer.

References

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- W.J. Brownlie, M.A. Sutton, K.V. Heal, D.S. Reay, E.M. Spears (eds.), (2022) *Our Phosphorus Future*. UK Centre for Ecology & Hydrology, Edinburgh. doi: 10.13140/RG.2.2.17834.08645
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