# Project Name:

#### Evaluating P sorption in P-sorbing media (PSM)

# Project Team

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# Objectives

1. Evaluate relationship between particle size and P removal:
   1. Is particle size significant for P sorption?
2. Evaluate elemental composition effects on P removal
   1. What elements best explains P removal?

# Milestones

1. Perform experiments, get data from outsourced laboratory
2. Format data sets for input into R
3. Generate exploratory analysis graphs, first presentation
4. Test regression models to identify the best model(s) to help address the objectives of the study, second presentation
5. Reporting the results

# Background

Phosphorus (P) is an essential nutrient for crop development and growth. However, in agricultural landscapes P may be transported in surface runoff or subsurface drainage from fields to water bodies as dissolved reactive P (DRP) or particulate P.

While high concentrations of crop-available soil P is beneficial to crop production, the high water solubility increases the potential P loss as DRP in either surface runoff or tile drainage effluent, Non-point agricultural sources contribute an estimated 48% of total P load to Illinois rivers [1].

The Illinois Nutrient Loss Reduction Strategy (IL NLRS) proposes best management practices (BMPs) to reduce the state’s P load by a target of 45% of the 1980-1996 annual mean , corresponding to an annual reduction of 4.1 million kg from non-point sources. Many BMPs are in-field practices such as cover cropping and no-till or conservation tillage. While these practices have demonstrated benefits for reducing erosion-driven P loss (i.e., particulate P) [2,3], downsides include the termination of cover crops which incurs extra costs and passes through the field for planting and spraying [4,5]. These practices focus on reducing particulate P losses from agricultural fields, but are less effective to reduce soluble P losses and may possible increase DRP losses [6,7].

Edge-of-field P filters (EFPFs) are an upcoming practice that employ a P-sorbing medium (PSM) to remove DRP from water exiting agricultural fields as surface run-off or tile drainage effluent. Generally, PSM are industrial by-products or waste materials of generally low-cost and ample quantity and therefore high economic potential for reutilization to remove P from wastewaters. EFPFs are an off-field option for farmers that does not require additional management time for farmers, are low maintenance, and a small footprint but are not currently included as a best management practice in the IL NRLS [8,9]. The goal of deploying EFPFs is to reduce transfer of soluble P from agricultural fields to surface waters. Evaluation of EFPFs in agricultural landscapes is needed to assess field-scale feasibility before potential integration into the IL NLRS. The PSM needs to have a high P sorption capacity to remove DRP. Potential PSM that have been evaluated include steel slag (SS) [10,11] and acid mine drainage treatment residuals (AMDR) [12,13].

P removal is thought to be highly correlated with particle size, with a smaller particle size removing more P. The effect of elemental composition on P removal has not been investigated. The main elements thought to impact P removal are Ca, Mg, Fe, and Al.

It would be useful to understand which elements have the greatest impact on P removal to target PSM sources that have higher amounts of that particular element or to manipulate PSM to be coated in it.

# Methodology and Technical Approach

*I compiled P sorption, initial concentration, and elemental composition data into a R compatible format and uploaded it. I created dataframes that were subset by PSM type. I made the size fractions a factor for the analysis. I plotted the P sorption for each particle sizes for steel slag 1 (SS1) against the initial P concentration to visualize the differences and I did the same for steel slag 2 (SS2).*

*For objective 1, I fit a linear model to see if size, source, and initial concentration are significant in P sorption. I did this for the entire dataset and then looked at the two types (SS and AMDR) separately. I ran a stepwise regression to determine the best model to predict P sorption with particle size, type of PSM, source of PSM, size of PSM, initial concentration, and P removal as predictor variables.*

*I then wanted to determine which elements best predict P sorption by PSM. I ran a stepwise regression for all of the data and then by the subset data for SS and AMDR.*

# Files

*All files pertaining to the Independent Project can be found* [*here*](https://github.com/taylorberkshire/IndependentProject)*.*

# Results & Discussion

*For objective 1, I found that in the linear model (Psorbed ~ Type + Size + Init\_Conc + Source)*, *size and source are significant to P sorption rates and explained 91.14% of the model which seems high but makes sense with other literature. The ‘large’ size is the only size that was significant, and it was a negative effect on P removal. This makes sense on a chemical sense as well because there is less surface area, therefore less sorption sites for P removal to occur. This is helpful as the tradeoff with particle sizes is between P removal and hydraulic conductivity, seeing that only the largest size was statistically different, means that larger than the smallest particle sizes can be used and still achieve similar P sorption, while maintaining a higher flow through rate for water. Unsurprisingly, the best model to explain P sorbed without the elemental composition is the initial concentration and the P removal (as a percent) as those how much A close up of a map

Description automatically generatedP is added is related to how much is sorbed and P removal uses P sorbed to determine the percent removed.*

*A close up of a map

Description automatically generated*

*For objective 2, the linear model including all of the elements explains 91.68%, which is only slightly higher than the model without the elemental composition (91.14%). This means that the majority of the variation can be explained due to particle size, source, and type, rather than the specific elemental composition. The stepwise regression showed the best model for all of the data (SS & AMDR) together is the initial concentration, P removal, total aluminum, water-soluble magnesium, and source of the PSM. For only the SS data, the best model includes the predictor variables of the initial concentration, P removal, total calcium, total magnesium, and water-soluble magnesium. This is consistent with the hypothesis that calcium and magnesium are the binding components of P for steel slag. For the AMDR data, the stepwise regression had the initial concentration and P removal as the predictor variables for the best model. I do not think this is the best representation though because the AMDR had 100% P removal so the P sorption was the maximum that it could be across all initial concentrations so there was no way to determine if elemental composition impacted P sorption. For future experiments, the initial concentration of P should be increased to see if P sorption will decrease with AMDR and the effect of elemental composition may be able to be determined then.*

# Conclusions

*From this analysis, I am able to conclude that size and source are significant to P sorption by the PSM and explain a large portion of the variation. The analysis also supports that P is removed by SS through calcium and magnesium and that these elements can be used as predictors in P sorption. The specific elemental composition of the different types and sources is not as important for predicting P sorption even though they are the chemical reason P is being removed.*

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