Legacy phosphorus desorption from U.S. Mid-Atlantic agricultural soils

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BACKGROUND

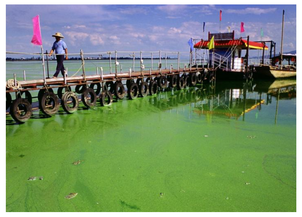
Chicken manure contains Phosphorus which is a vital nutrient in plant growth and crop production.

The repeated addition of Phosphorus leads to build up of the nutrient.

Due to leaching, erosion, and runoff, Phosphorus can enter water systems causing eutrophication.

Over nourishment of Phosphorus promotes algae growth which may cause anoxic conditions leading to fish kills.

What Phosphorus species are in the soil and what is their mobility?



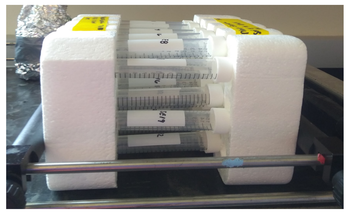
OBJECTIVES

1. Determine the rate of P loss in soil through desorption experiments.
2. Determine the strengths of P bound to other soil compounds by comparing the curves collected from different desorbing agents.
3. Determine speciation at micron scale

METHODS

Soil samples were sieved through a 2 mm sieve and sent to the soil testing lab to determine:

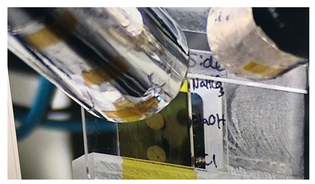
- Mehlich 3-routine analysis (agronomic need P)
- Microwave acid digestion (total P)
- Particle size analysis



Desorption experiments were completed by placing 200 mg of soil with 10 ml of desorption agents. These were then placed on the shaker at 200 rpm.

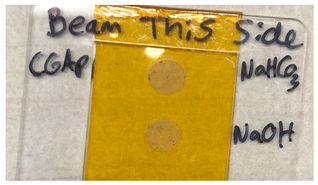
- Pore water (0.01M KCl)
- Acid rain (0.1M HNO_3)
- Ligand exchange mechanisms (0.1mM Na_2SiO_3)

Samples taken at 0.5hr, 1hr, 2hr, 3hr, 6hr, 12hr, 24hr, 48hr, and 72hr intervals



Soil samples were powder mounted to preserve natural structures then analyzed using synchrotron radiation:

- Beamline TES for tender energy elements (Si, P, S, and Al)
- Beamline XFM for other elements of interest (Fe, Ca, Mn and Mg)



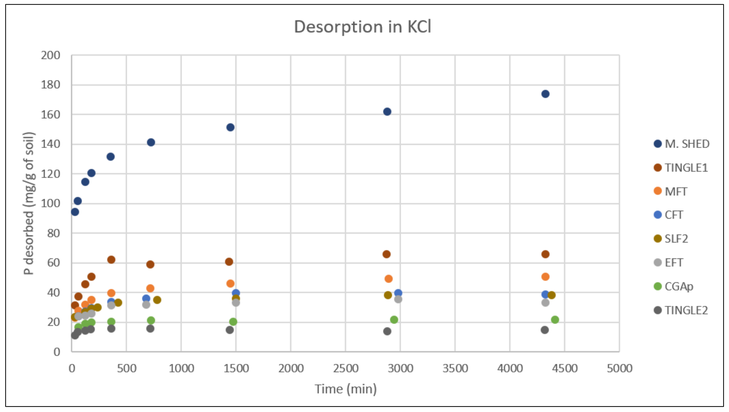
Soils powder mounted onto tape in order to not disturb structures of soil so imaging is more accurate to its natural environment.

RESULTS

Sample ID	Textural Class	M3-P (mg/kg)	P (mg/kg)	M3-Ca (mg/kg)	Ca (mg/kg)
CFT	Loam	256	482	807	984
MFT	Loam	331	551	698	885
EFT	Loam	303	726	1063	1298
CGAp	Silt Loam	198	937	773	1099
Manure Shed	Silt Loam	1121	2004	2061	3380
SLF2	Silt Loam	634	1109	1279	1691
Tingle 13-14	Loamy Sand	607	1023	646	944
Tingle 19-20	Loamy Sand	356	974	819	1264

Figure 1 (left): Soil texture and composition of each soil sample with respect to their separates. The concentrations of the elements of interest in each soil following Mehlich III extraction and EPA3051 (specific acid digestion method).

Figure 2 (below): Average values of the concentration of P in all samples at each time interval that was collected.



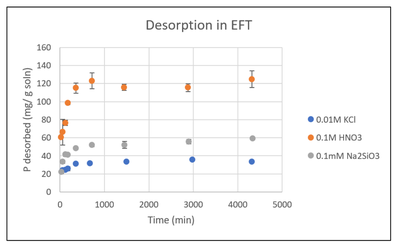


Figure 3: Average values of the concentration of P in all samples of EFT collected at each time interval and each desorption agent.

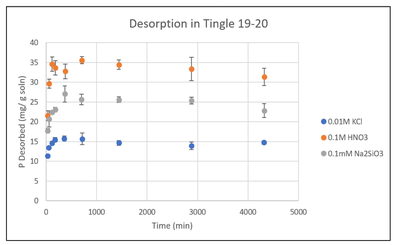


Figure 4: Average values of the concentration of P in all samples of Tingle 19-20 collected at each time interval and each desorption agent.

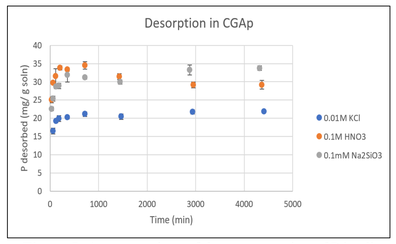


Figure 5: Average values of the concentration of P in all samples of CGAp collected at each time interval and each desorption agent.

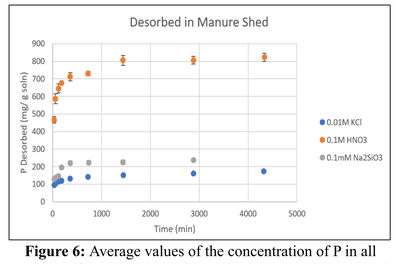


Figure 6: Average values of the concentration of P in all samples of Manure Shed collected at each time interval and each desorption agent.

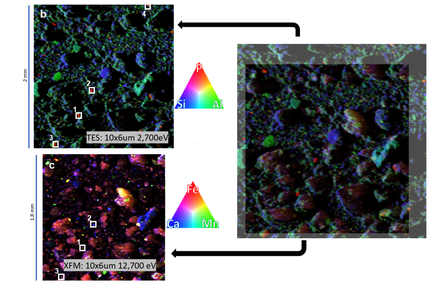


Figure 7: Overlay of XFM and TES µXRF maps of powder mounted EFT soil (<250 µm) in order to show P and other co-located elements.

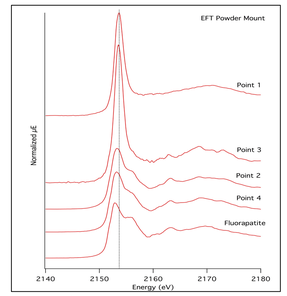
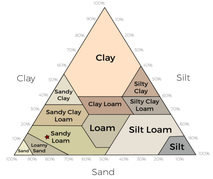
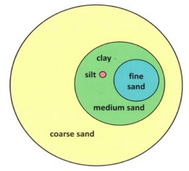


Figure 8: The TES u-XANES spectra of each point of EFT presented together to help distinguish the P species present at that location.

DISCUSSION

- The silt loam soils had the highest total P from the EPA 3051. The higher percentage of silt and clay and lower percentage of sand may be part of the reason for the high total P in these soils.





- Results for manure shed indicate a lot of loosely held P that is highly susceptible to transport off the field
  - Had the highest P desorption in 0.01M KCl at around 160 mg/kg
  - At 56%, a large portion of the total P was extracted with Mehlich III
- CGAp likely has the most tightly held soil P.
  - had the lowest percent of Mehlich III extractable P at 21%
  - Had low equilibrium desorbed P in 10 mM KCl at 22 mg/kg
- EFT has a higher percentage of sand, which may be why it contains a higher Mehlich 3 P when compared to CGAp.
- Consistently KCl desorbs the least P. We used KCl to mimic the effect of pore water, which means pore water alone may not be a major contributor to P leaving soils.
- Across all soils, the 0.1 mM Na_2SiO_3 desorbed more P than the 10 mM KCl. This indicates that we may be extracting more tightly held P, perhaps by ligand exchange.
- The desorption experiments completed using HNO_3 at pH 4 also desorbed more P than KCl and Na_2SiO_3, especially for soils with high Ca. Manure shed had the highest Ca and desorbed the most HNO_3 P by far. This may indicate preferential P desorption from the dissolution of calcium phosphate minerals (like fluorapatite).
- Comparison of the TES and XFM u-XRF maps show that the majority of P species probed in EFT are clearly associated with Ca, potentially in the form of fluorapatite.

Ongoing and Future Work

- Future/ongoing extracting agents:
  - 1 mM Na_2SiO_3 (to compare with 0.1mM Na_2SiO_3)
  - 1 mM sulfate and 10 mM sulfate (to mimic some effects of sea level rise)
- We will fit the desorption data to curves and do statistical analysis to test significance.

Acknowledgements

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USDA United States Department of Agriculture National Institute of Food and Agriculture