

# Evaluation of Plant-Available Phosphorus of Dried Residuals from Wastewater Processed for Phosphorus Reduction with Aluminum or Iron

M. Gomez Botero, A. P. Mallarino, M. U. Haq, M. L. Thompson, J. E. Sawyer  
Iowa State University

50<sup>th</sup> Annual

NORTH CENTRAL EXTENSION-INDUSTRY  
SOIL FERTILITY CONFERENCE

18-19 November, 2020

## Introduction and Objectives

- Wastewater effluent from industrial and municipal water treatment plants requires phosphorus (P) removal before being discharged to surface waters
- There is special interest in a procedure by which P is removed from final plant effluent following biological treatment by chemical precipitation using aluminum (Al) sulfate or iron (Fe) chloride
- This procedure results in a semi-solid mostly inorganic residual material that can be dewatered before land application or handled as a slurry
- There is very scarce research concerning the P plant-availability of this type of residual product,

### Objectives

- Evaluate the chemical composition of dried wastewater residuals processed for P reduction with aluminum sulfate or iron chloride
- Assess the P crop-availability of these wastewater residuals compared with monocalcium phosphate (the P compound in triple superphosphate fertilizer) under the controlled conditions of a greenhouse study



## Materials and Methods

- Dried wastewater sludges treated with aluminum sulfate or iron chloride (abbreviated hereon as AIP and FeP) were analyzed for moisture, total elemental composition, extractable elements by water, and ammonium-citrate EDTA extracted P
- The P plant-availability of the AIP and FeP sludges relative to monocalcium phosphate (MCP) was evaluated in a greenhouse study with annual ryegrass in pots using topsoil from the Iowa soil series Harps (Typic Calciaquolls), Nicollet (Aquic Hapludolls), and Zook (Cumulic Vertic Endoaquolls)
  - Moist soil was sieved through a 4-mm screen and air-dried
  - A base nutrient solution of N, K, S and micronutrients was sprayed and thoroughly mixed with the air-dried soil
- Total P amounts to attain concentrations of 0, 25, 50, 100, 150, and 200 ppm P replicated four times were mixed with 2.54 pounds of soil
  - The AIP and FeP sludges and MCP were ground to pass a Tyler mesh size 80
- Ryegrass was cut four times at 1 inch from the soil level when most leaves were 8 inches tall, the biomass was dried at 65 °C, weighed, and ground to determine dry matter yield, P concentration, and P uptake
- The percent P crop-availability of the wastewater sludges relative to MCP was calculated from the total plant P uptake across cuts by comparing the slopes (b coefficients) of linear equations fit to approximately linear response to the four lowest P rates for each soil and P source

# Evaluation of Plant-Available Phosphorus of Dried Residuals from Wastewater Processed for Phosphorus Reduction with Aluminum or Iron

M. Gomez Botero, A. P. Mallarino, M. U. Haq, M. L. Thompson, J. E. Sawyer

Iowa State University

50<sup>th</sup> Annual

NORTH CENTRAL EXTENSION-INDUSTRY  
SOIL FERTILITY CONFERENCE

18-19 November, 2020

**Table 1.** Selected chemical properties of the wastewater materials used (105°C dry basis)

Test	AIP	FeP	MCaP
Moisture (%)	13	3.4	--
Total carbon (C, %)	4.7	3.3	--
Total nitrogen (N, %)	1.1	0.8	--
Total phosphorus (% P <sub>2</sub> O <sub>5</sub> )	26.6	23.4	48.1
Total sulfur (S, %)	0.6	0.2	--
Total aluminum (Al, %)	23.5	0.0	--
Total calcium (Ca, %)	2.8	3.3	--
Total iron (Fe, %)	0.4	42.7	--
Ammonium-citrate/EDTA soluble P (% P <sub>2</sub> O <sub>5</sub> )	3.8	3.2	48.1
Water-soluble P (% P <sub>2</sub> O <sub>5</sub> )	0	0	45.1
Water-soluble Al (%)	0	0	--
Water-soluble Ca (%)	0.045	0.047	--
Water-soluble Fe (%)	0	0.003	--

**Table 2.** Initial soil-test values of Harps, Nicollet and Zook soils

Soil Test	Harps	Nicollet	Zook
Mehlich-3 P (ppm)	10	3	16
pH	7.8	6	7.1
Organic carbon (C, %)	4.0	2.4	2.4
Inorganic carbon (C, %)	17.3	0	0
Clay (%)	34	24	41

## Results and Discussion

### Plant Dry Matter Yield

- There were large biomass yield increases from P application for Harps and Nicollet soils, which had very low initial P, and very smaller increases for Zook, which had higher initial P
- Maximum yield attained by P applied with AIP and MCaP was approximately similar for each of the three soils. Maximum yield with FeP was lower for all soils, but especially for Harps
- FeP was the least effective source at increasing yield since it did not attain the maximum yield attained with MCaP and AIP, and its efficacy was especially low for the Harps calcareous soil
- MCaP was more effective than AIP for the Harps calcareous soil (attained the maximum with lower P rates) but the sources did not differ for the Nicollet and Zook soils

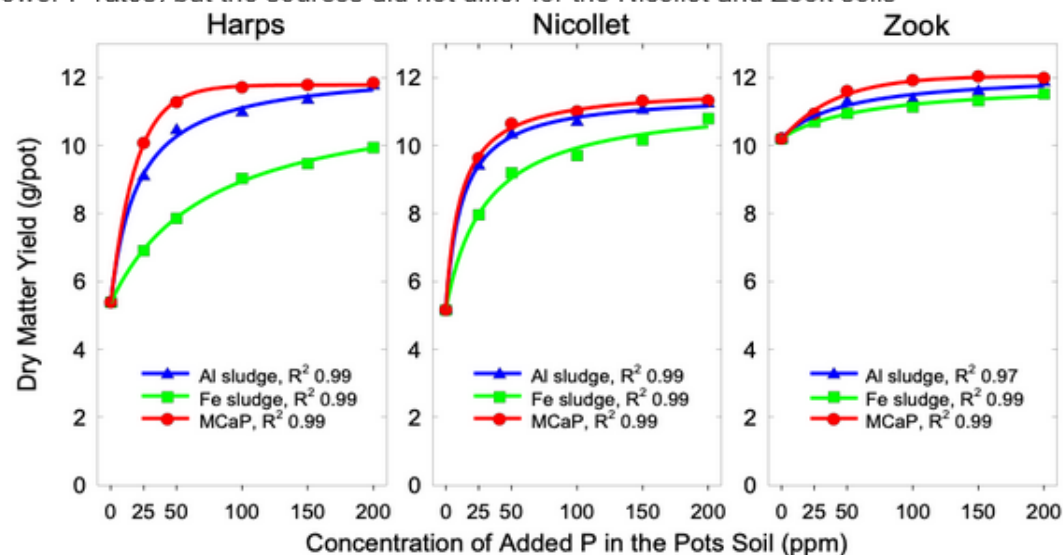


Figure 1. Total ryegrass dry matter yield across all cuts as affected by applied P for three soils and three P sources.

# Evaluation of Plant-Available Phosphorus of Dried Residuals from Wastewater Processed for Phosphorus Reduction with Aluminum or Iron

M. Gomez Botero, A. P. Mallarino, M. U. Haq, M. L. Thompson, J. E. Sawyer  
Iowa State University

50<sup>th</sup> Annual  
NORTH CENTRAL EXTENSION-INDUSTRY  
SOIL FERTILITY CONFERENCE  
18-19 November, 2020

## Plant P Concentration

- There were large biomass P concentration increases from P application for all soils, including the Zook soil for which the yield response was small due to higher initial soil P
- Differences between P rates were much larger than for yield, and the largest rate resulted in the largest P concentration with the only exception of the Nicollet soil with FeP
- Luxury uptake of P has been observed for vegetative tissue, and in this study allowed for better assessment of the sources P availability
- The maximum P concentrations attained with FeP were the smallest for all soils and, in contrast to yield results, the maximum concentration attained with AIP was smaller than with MCaP and closer to that with FeP

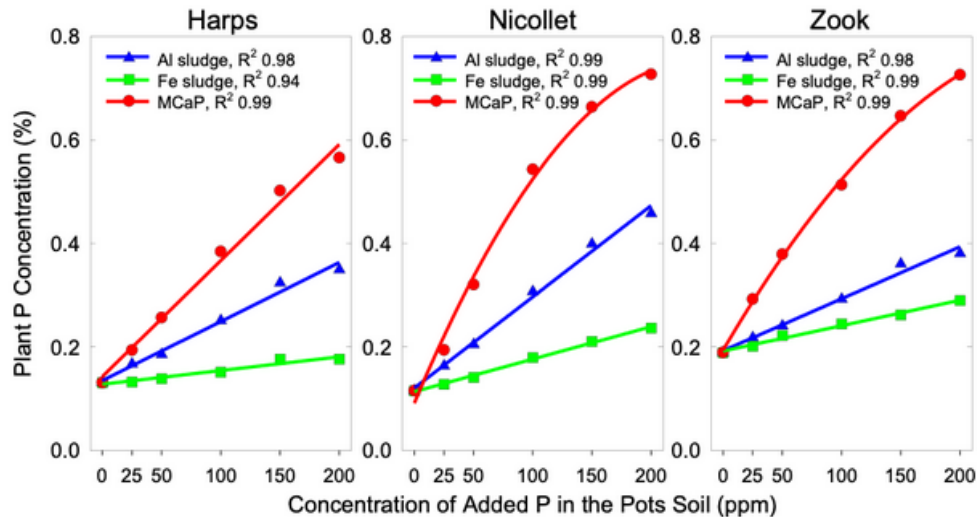


Figure 2. Average ryegrass P concentration across all cuts as affected by applied P for three soils and three P sources.

## Plant P Uptake

- P uptake results followed more closely the results for P concentrations since the P uptake increases from applied P were larger than for yield, especially for the Zook soil
- Differences between P application rates were proportionally larger than for yield, and the largest P rate produced the largest P uptake for all soils and materials
- For Harps and Nicollet soils, AIP maximum P uptake and applied P efficiency were in between those for FeP and MCaP
- For the Zook soil, which had the finest texture, AIP maximum P uptake and applied P efficiency were closer to those for FeP than for MCaP

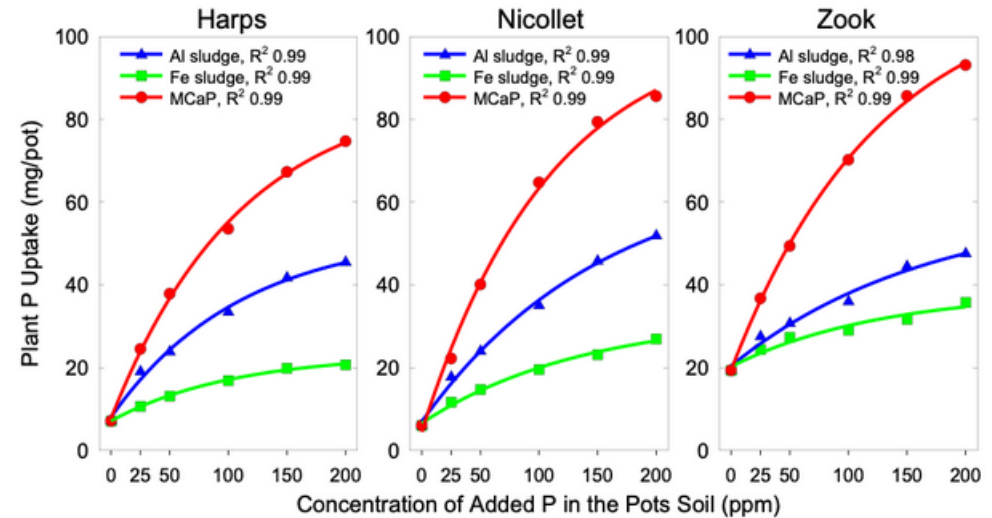


Figure 3. Average ryegrass P uptake across all cuts as affected by applied P for three soils and three P sources.

# Evaluation of Plant-Available Phosphorus of Dried Residuals from Wastewater Processed for Phosphorus Reduction with Aluminum or Iron

M. Gomez Botero, A. P. Mallarino, M. U. Haq, M. L. Thompson, J. E. Sawyer  
Iowa State University

50<sup>th</sup> Annual

NORTH CENTRAL EXTENSION-INDUSTRY  
SOIL FERTILITY CONFERENCE

18-19 November, 2020

## Conclusions and Acknowledgements

- P plant-availability of wastewater processed for P reduction with aluminum sulfate and iron chloride relative to monocalcium phosphate for the three soils was 55 and 21%, respectively, for Harps, 48 and 22% for Nicollet, and 32 and 19% for Zook
- The results of the study are useful to make preliminary decisions about agronomic application rates for a sustainable recycling of P in these wastewater residuals
- However, the relative efficiencies determined by this greenhouse study should be corroborated by evaluations at the field and for a longer period of time in soils with contrasting chemical properties

### Acknowledgements

We recognize funding by the Iowa Nutrient Research and Education Council