Phosphorus Release from Sewage Sludge Incinerator Ash

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Introduction

The Metropolitan Wastewater Treatment Plant in downtown St. Paul, MN is among the nation's largest wastewater treatment facilities, processing 172 million gallons of wastewater a day. Additionally, they incinerate sewage sludge for energy, producing over 5 MW of power per day from the three fluidized bed reactors. However, **38 tons of ash are landfilled each day** after incineration.

This ash contains significant amounts of phosphorus and could be beneficially reused as an agricultural fertilizer. Early studies of this ash, prior to tightened EPA regulation on industrial waste, raised concerns about metal concentrations (Bierman and Rosen 1994a, Bierman and Rosen 1994b, Bierman et al. 1995). However, a recent greenhouse study (Crants and Rosen, 2015) demonstrated the ash's viability as a phosphorus fertilizer with minimal trace metal concentrations.

Importance

Phosphorus is a limited, mined, and nonrenewable resource. 70% of known reserves are in Morocco, making future production heavily reliant on an imported product from a single country (USGS).

Phosphorus is used inefficiently. Once applied as fertilizer, phosphorus contained in plant biomass is ingested by humans, processed as sewage, and often landfilled.

Objectives

We performed a 32-day incubation to model the release of phosphorus and metals in soil. We sought to:

- **Describe and compare phosphorus release over time from the amendment of sewage sludge ash, triple super phosphate, and other beneficial-reuse products such as biosolids and struvite**
- **Describe and compare metals release over time, specifically copper and zinc**

Methods

We conducted a randomized block experiment to compare conventional triple super phosphate (TSP), sewage sludge incinerator ash (ASH), dried, pelletized biosolids (BS), and commercial struvite (STR) at various rates ranging from 0.0x to 2.0x. **At the 1.0x rate, we applied 90 kg P_2O_5/ha**.

TSP: 0.0x, 0.5x, 1.0x, 1.5x, 2.0x
Ash: 0.0x, 0.5x, 1.0x, 1.5x, 2.0x
Biosolids: 1.0x, 2.0x
Struvite: 1.0x, 2.0x

For each sample, 300 grams of Waukegan silt loam from Rosemount, MN were brought to 80% field capacity and pre-incubated for 7 days before the fertilizer was applied. Treatments were replicated four times and samples were taken at 0, 2, 4, 8, 16, and 32 days. Enough jars were prepared such that each jar was a sampling date. All jars were incubated at 22˚C and opened every 3-4 days to allow for oxygen replenishment. Bray-P, Olsen-P, 1:1 water:soil and DTPA extractions were done by AgVise Laboratories. The data were analyzed in SAS using a repeated measures ANOVA.

NPK:

	Total N	NH4-N	Available P_2O_5	Total P_2O_5	Soluble K_2O	Total K_2O
TSP	0.20%	0.00%	44.13%	44.61%	0.00%	0.51%
ASH	0.00%	0.00%	13.60%	25.71%	2.33%	3.78%
BS	5.37%	0.37%	7.60%	8.41%	0.13%	0.58%
STR	5.40%	0.07%	27.09%	27.39%	0.00%	0.45%

EPA 503 Metals* (mg/kg):

	As	Cd	Cr	Cu	Pb	Hg	Mo	Ni	Se	Zn
TSP	13.5	15.43	350	65	5	0.008	1.4	32.8	NT	417
ASH	28	8.2	149	2255	128	2.513	56.6	89.9	12.8	2983
BS	12.8	1.65	38	1066	24	0.415	22.7	27.8	4.5	1106
STR	2.0	0.4	5.0	ND	0.2	ND	4.0	2.0	ND	2.0
EPA PC**	41	39	1200	1500	300	17	--	420	36	2800

Loading Rates at 90 kg P_2O_5/ha* (kg/ha/yr):

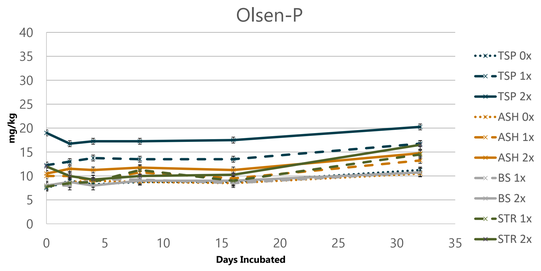
	As	Cd	Cr	Cu	Pb	Hg	Mo	Ni	Se	Zn
TSP	0.003	0.003	0.071	0.013	0.001	0.000	0.000	0.007	ND	0.085
ASH	0.019	0.005	0.099	1.492	0.085	0.002	0.037	0.059	0.008	1.974
BS	0.015	0.002	0.045	1.262	0.028	0.000	0.027	0.033	0.005	1.310
STR	0.001	0.000	0.002	ND	0.000	ND	0.001	0.001	ND	0.001
EPA APLR**	2.00	1.90	150.00	75.00	15.00	0.85	--	21.00	5.00	140.00

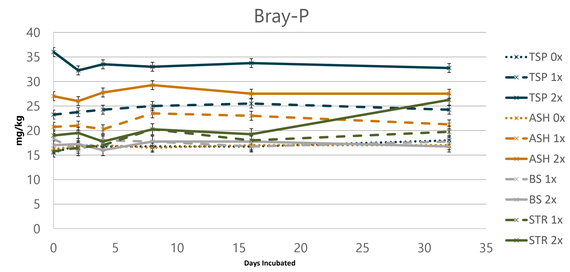
*Metals characterization taken from Crants and Rosen 2015

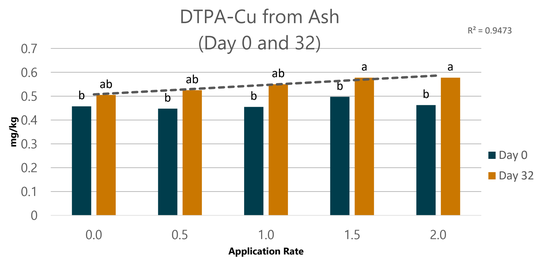
** Pollutation Concentrations and Annual Pollutant Loading Rate as stated by the EPA

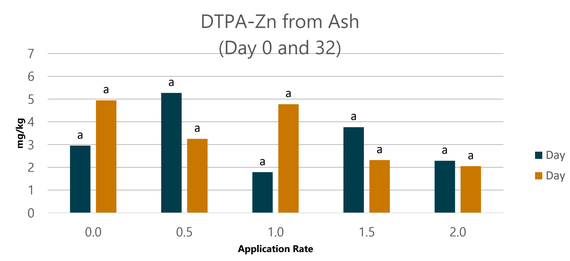
We are using EPA regulations as guidelines as they currently only apply to land application of biosolids. It is important to keep in mind that biosolids are applied based on nitrogen rather than phosphorus.

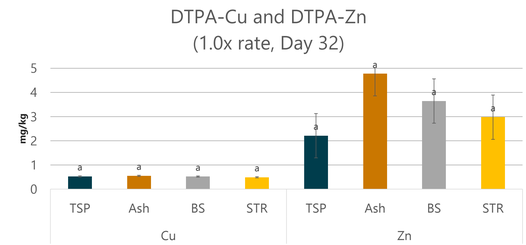
Results

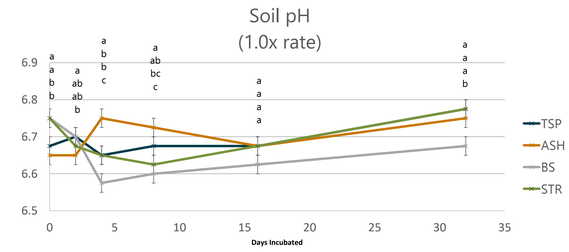












Conclusions

- The ash seems to **provide 25-30% less Olsen-P and 10-20% less Bray-P** than TSP even though both were applied based on citrate soluble phosphorus rates. Plant uptake and biomass data is required to verify this discrepancy. The difference in Olsen-P and Bray-P reflects the tendency for Bray-P, an acid extract, to overestimate available P from the basic ash.
- The type of fertilizer **amendment had no significant effect on extractable copper concentration levels** at the 1.0x rate. However, extractable copper increased with increasing ash application. The large variation within zinc data may indicate sample contamination.
- **pH was not significantly elevated** by any of the fertilizer treatments over the 32-day period.

We believe the incubation and previous greenhouse study provide enough evidence that sewage sludge incinerator ash can be a safe and viable phosphorus fertilizer due to the presence of plant available phosphorus and low levels of copper and zinc.

Next Steps

- Day 64 is currently being analyzed.
- We have completed the first of three seasons in a corn/soybean rotational **field study** which will look at the chemical, physical, and microbial effects of these four phosphorus fertilizers. This study may also clarify the variation in Olsen-P and Bray-P amongst fertilizers.
- While these metals levels are still significantly below current EPA standards for biosolids, we will continue to monitor copper, zinc, and other EPA 503 metals in future studies.
- We are considering the usage of **phosphorus solubilizing bacteria** to biologically increase plant available phosphorus in the ash to make it a more effective fertilizer.

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