NC STATE UNIVERSITY
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Determination of Biosolids Phosphorus Solubility and its Relationship to Wastewater Treatment

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Introduction

Biosolids are land applied as a fertilizer and soil amendment. In NC, the USEPA Part 503 standards for beneficial reuse govern application rates based on biosolids plant-available N and the agronomic N needs of the crop on the receiving soil. Differences between biosolids and crop N:P cause N-based biosolids applications to surpass crop P needs, creating excess soil P and increasing the risk of surface water pollution and subsequent eutrophication, algae blooms (Fig. 1), and fish kills (Fig. 2). The NC Department of Environment and Natural Resources (NC DENR) is considering P-based guidelines for biosolids in some nutrient-impaired watersheds. The P Loss Assessment Tool (PLAT) will be used to estimate biosolids P-loss risk. To use PLAT, the soluble P fraction must be quantified. However, forms and quantities of P in biosolids depend on wastewater treatment plant (WWTP) influent and treatment processes. Land application based on both P and N will likely decrease application rates, reduce the number of eligible receiving fields, & shorten the time soils can receive biosolids, thus making land application more costly. Hence, widespread adoption of a P-based approach may foster development of alternative beneficial uses of biosolids other than land application.

Figure 1: Algae blooms
http://2.bp.blogspot.com

Figure 2: Fish kills
http://1.bp.blogspot.com

Objectives

1. Determine treatment processes of NC's largest WWTPs and sample biosolids seasonally
2. Determine biosolids soluble P fractions for incorporation into NC PLAT to estimate P-loss
3. Explore relationships of treatment processes with biosolids total P and soluble P fractions

Assessing Phosphorus Loss Risk

The NC USDA Conservation Practice Standard for nutrient management (590) dictates that if applied P exceeds the agronomic rate, P-loss risk must be determined. PLAT was developed to do this for animal waste and commercial fertilizers. Once soluble P fractions are developed for biosolids, PLAT can be updated and used to guide P-based application rates in river basins containing nutrient impaired watersheds (Fig. 3).

Rating	Index Value	Consequence of Rating
Low	0-25	Nitrogen-based manure application rate
Medium	26-50	Nitrogen-based manure application rate
High	51-100	Manure application rate is limited to phosphorus removal from the site in the harvested crop
Very High	>101	No additional phosphorus application is allowed (except starter fertilizer P)

Table 1: Effect of PLAT rating on application of animal manure.

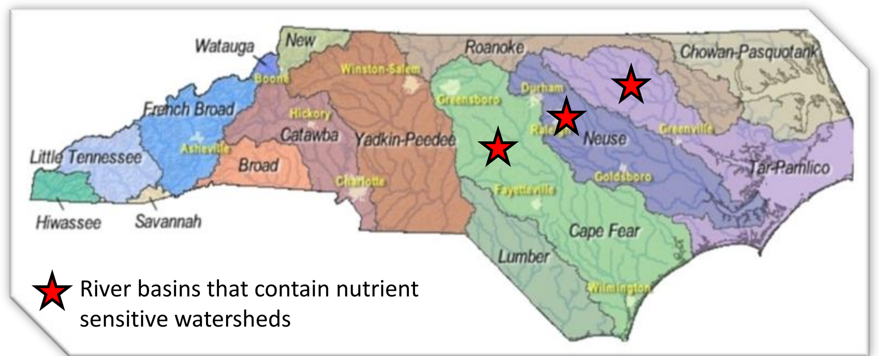

Figure 3: River basins of NC
http://nc.water.usgs.gov/realtime/

WWTP Process Effects on Solubility

Consistency

Liquid (~3% solids)

Cake (~20% solids)

Pellets (~90% solids)

Chemicals

- Hypothesized to lower P solubility fractions:
  - Flocculators with strong P adsorption to Al and Fe such as alum, ferric chloride, & ferrous sulfate
  - Alkalizers such as quick lime, calcium/sodium sulfate, & magnesium/sodium hydroxide

Class

- Class B: Must meet metal & pathogen limits & reduce vector attractants; have site-use & access restrictions.
- Class A: Further treated to reduce pathogens; have fewer application restrictions.
- Class A-Exceptional quality: meet stricter metal limits; NO application restrictions: lawns, home gardens, etc.

Processes

- Hypothesized to raise solubility fractions:
  - Biological Nutrient Removal (BNR) removes nutrients from wastewater using microorganisms for nitrification and denitrification, and microorganisms that store orthophosphate preferentially.

Materials and Methods

Survey

Operators in Responsible Charge (ORCs) of NC's largest WWTPs were surveyed using an online tool (Qualtrics), with questions corresponding to a generalized WWTP flowchart (Fig. 4). We will use cluster analysis to see the extent to which WWTPs may be grouped by processes.

Sampling & Analysis

Biosolids are being collected from ~30 WWTPs in NC for four seasons in 2013/2014, including biosolids with different chemical additions, treatment processes, and consistencies. Samples are being analyzed by dry ash digestion for total P and water-extracted for soluble P, with both fractions analyzed by Inductively Coupled Plasma (ICP) to determine soluble P/total P fractions. Relationships are being determined between P fractions and WWTP processes based on the WWTP survey. Preliminary results are shown in Figures 5-8.

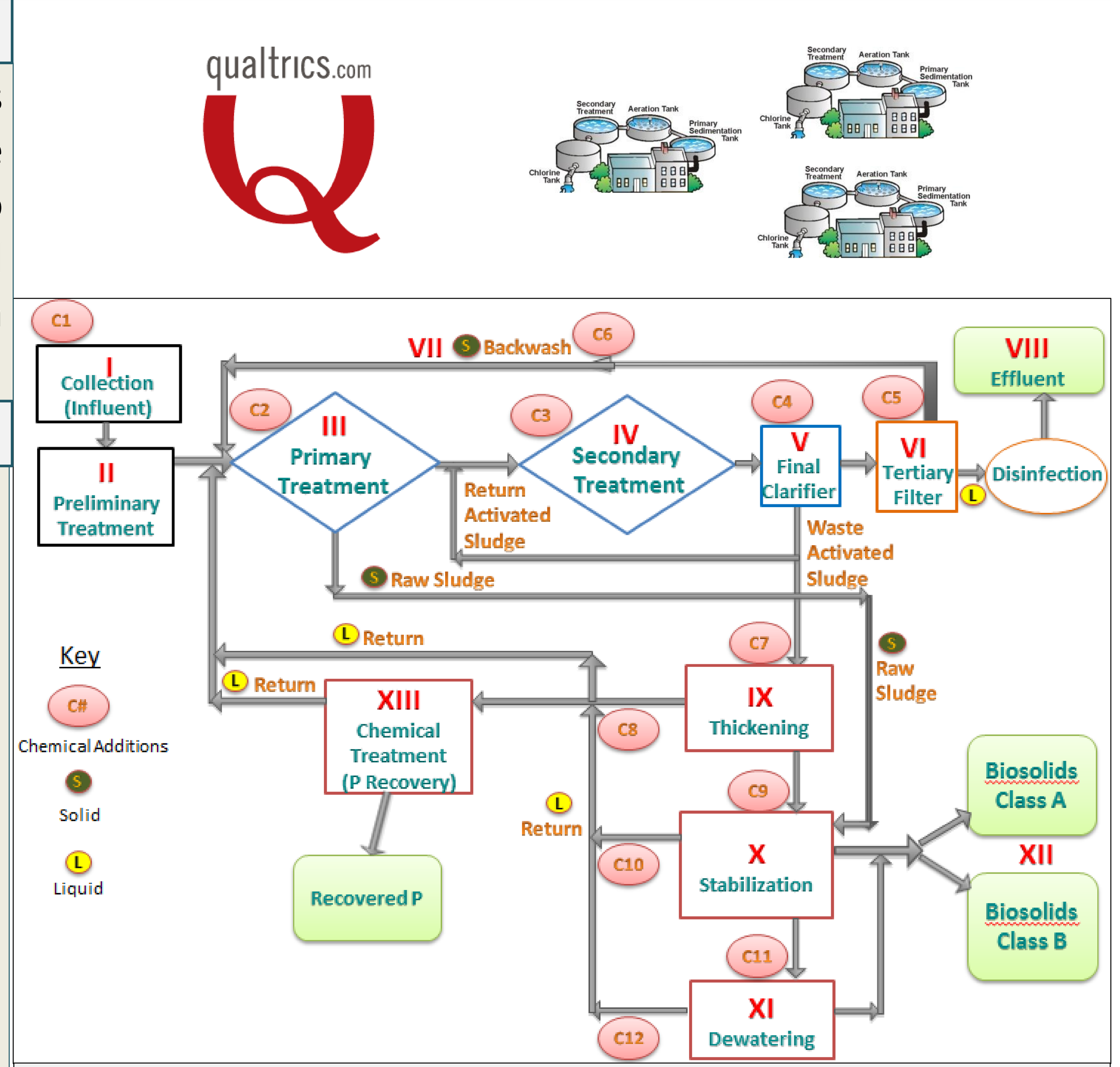

Figure 4: General WWTP Flowchart

Preliminary Results

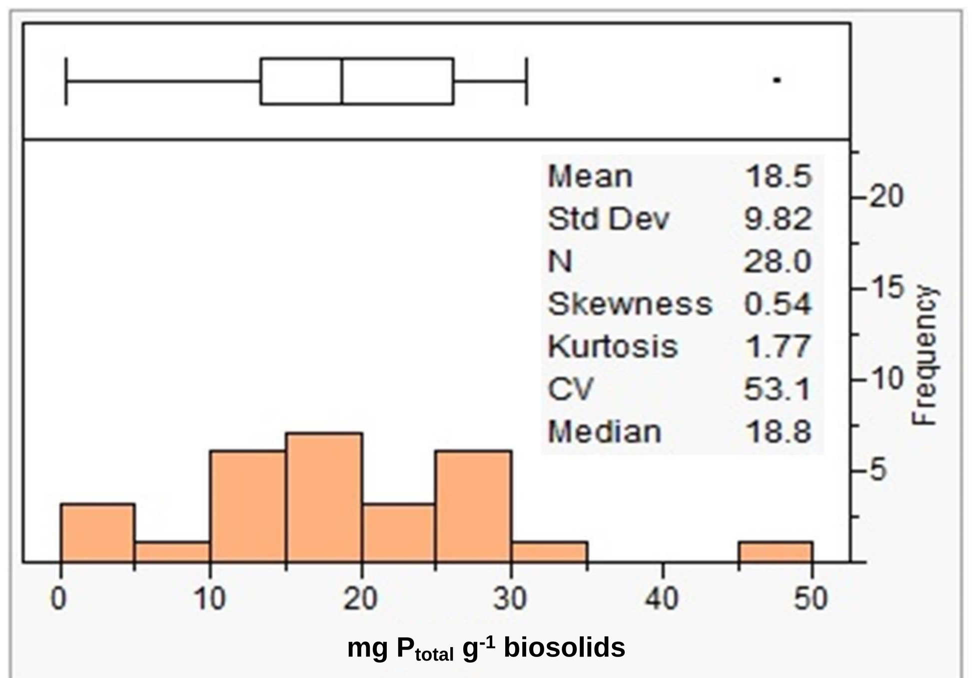

Fig. 5: Frequency distribution: total P

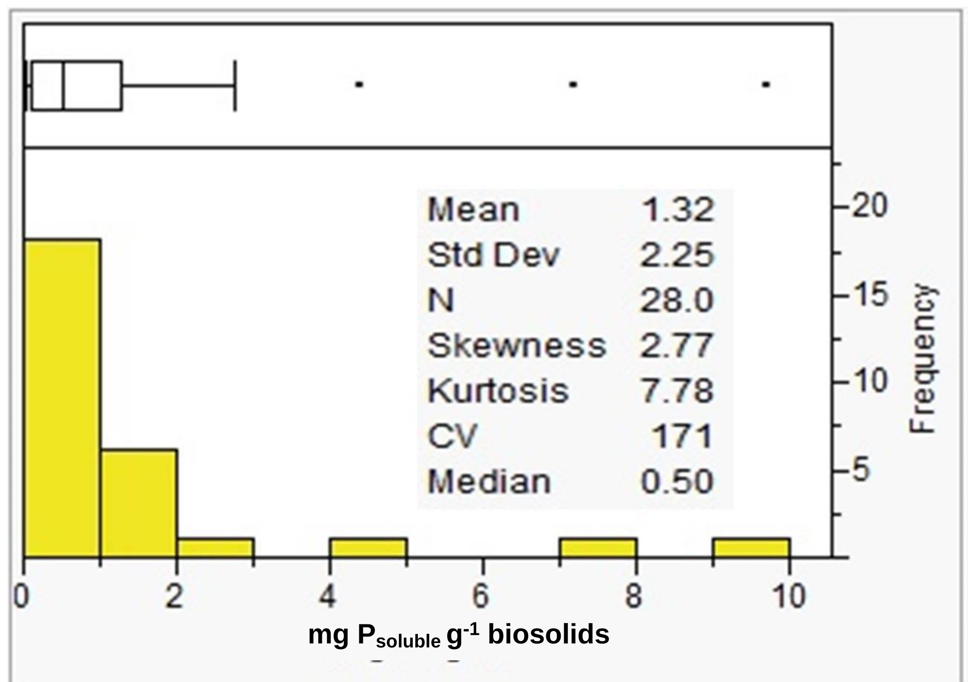

Fig. 6: Frequency distribution: soluble P

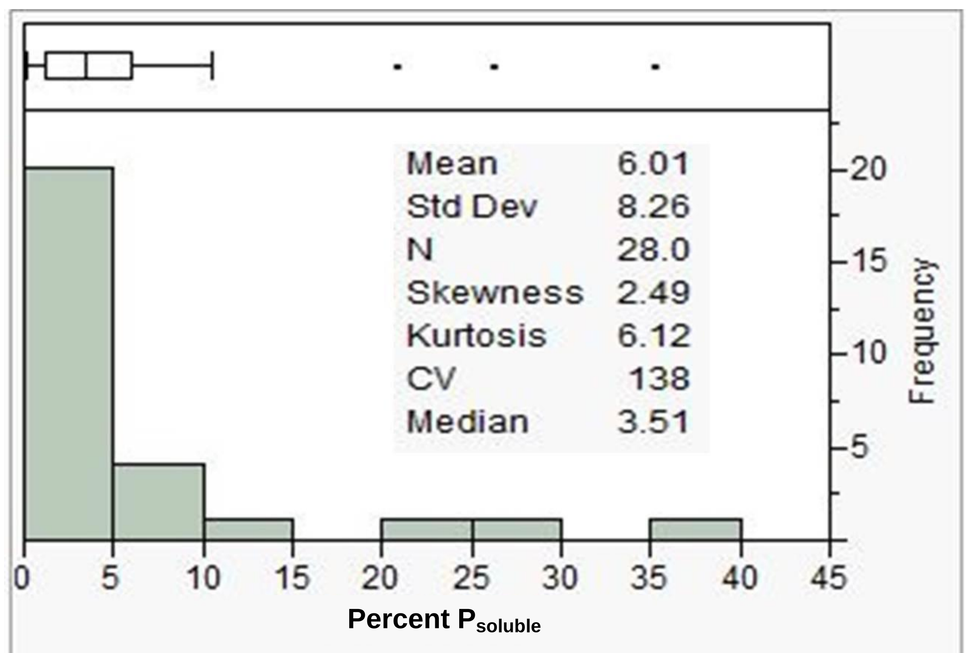

Fig. 7: Frequency distribution: % Soluble P ($P_{soluble}$ P_{total}^{-1})

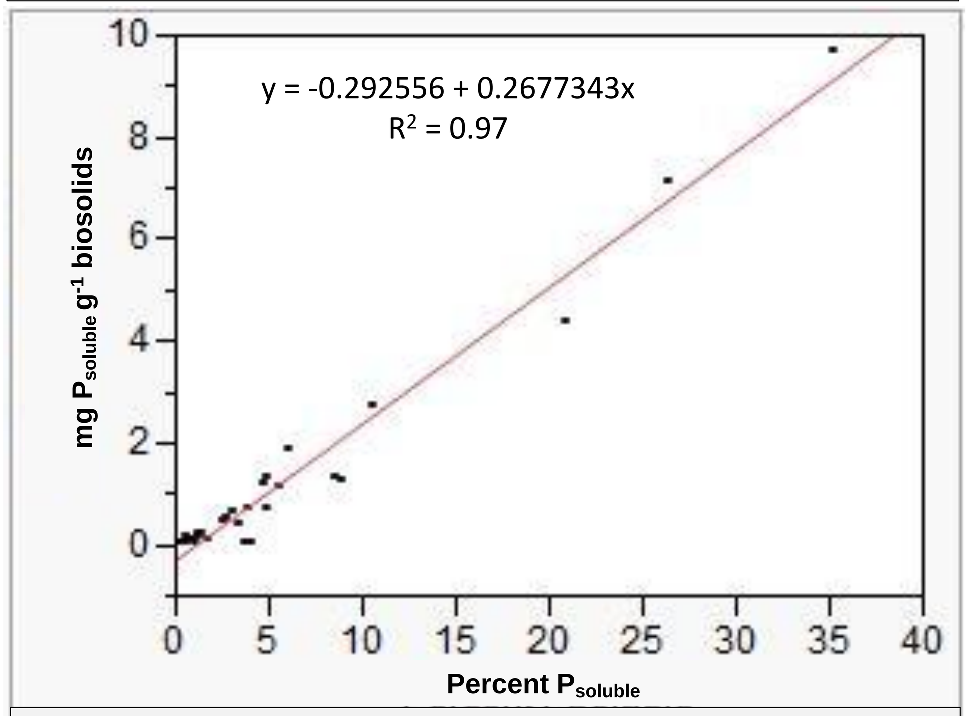

Fig. 8: Soluble P vs. Percent Soluble P

Preliminary Conclusions

Summer 2013 biosolids had a wide range of total P: 0.45 - 47.5 mg g^{-1} biosolids (Fig. 5) with a quasi-uniform distribution with low skew and kurtosis. Most biosolids had low soluble P (Fig. 6) and low soluble P fraction (Psoluble/Ptotal; Fig. 7), although some had soluble P fractions >20%. The distributions of soluble P and soluble P fractions were similarly strongly skewed and kurtotic. The soluble P fractions were strongly correlated (r^2=0.96, p <0.0001) with soluble P (Fig. 8). If these results are confirmed, they suggest that the soluble P fractions might be estimated solely on the basis of soluble P, i.e., without a total P analysis. It remains to be determined whether individual pooled soluble P fraction values can be allotted to groups of WWTPs with similar processes.

Acknowledgements

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