Addressing Variable Phosphorus Solubility of Amendments in the Watershed Model

CBP Modeling Workgroup
December 13, 2016

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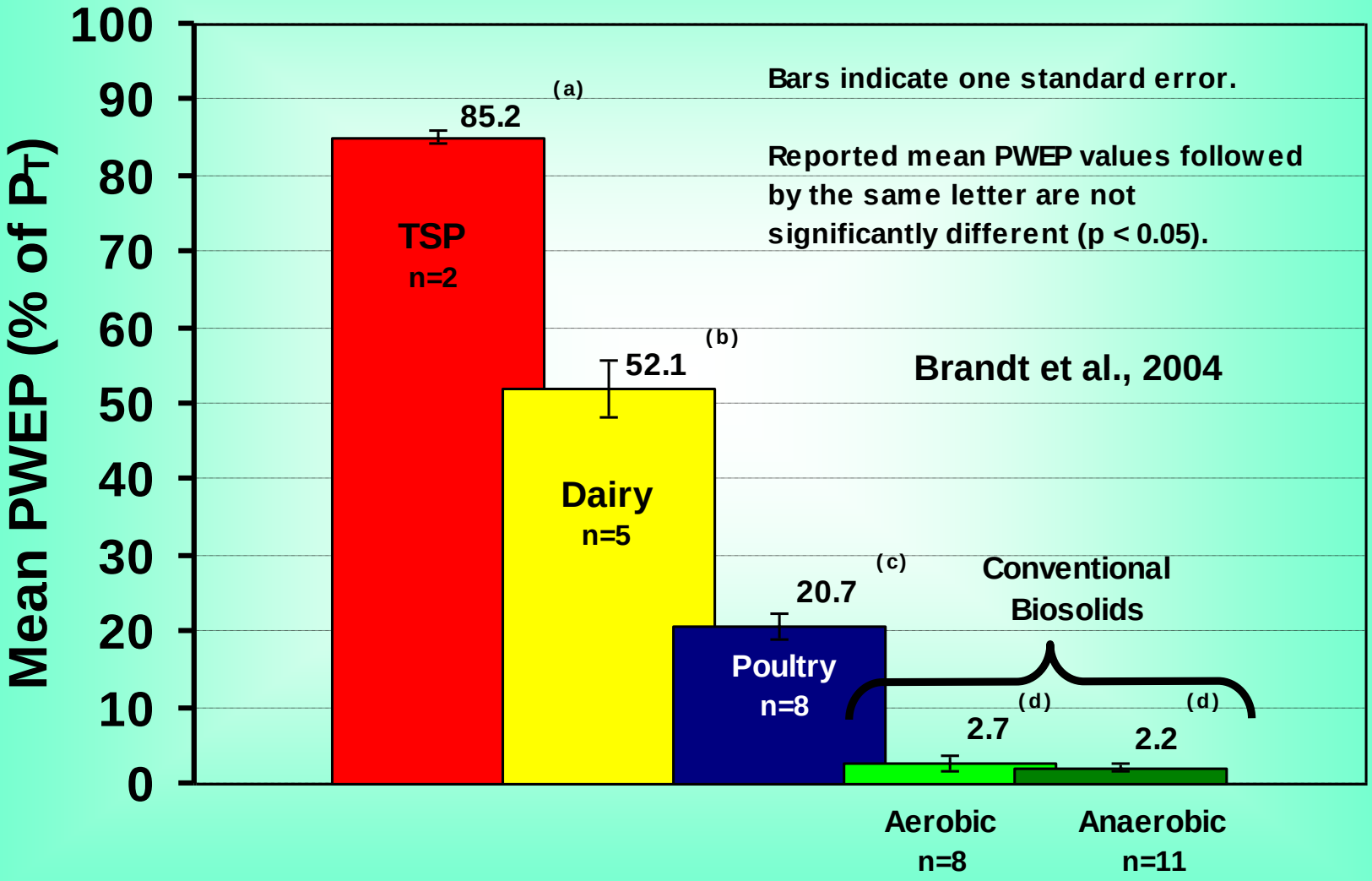
Presentation Outline

1. P Solubility of Amendments
2. Implications for P Runoff and Leaching
3. APLE Model Scenarios
4. Addressing Variable P Solubility

P Release from Amendments

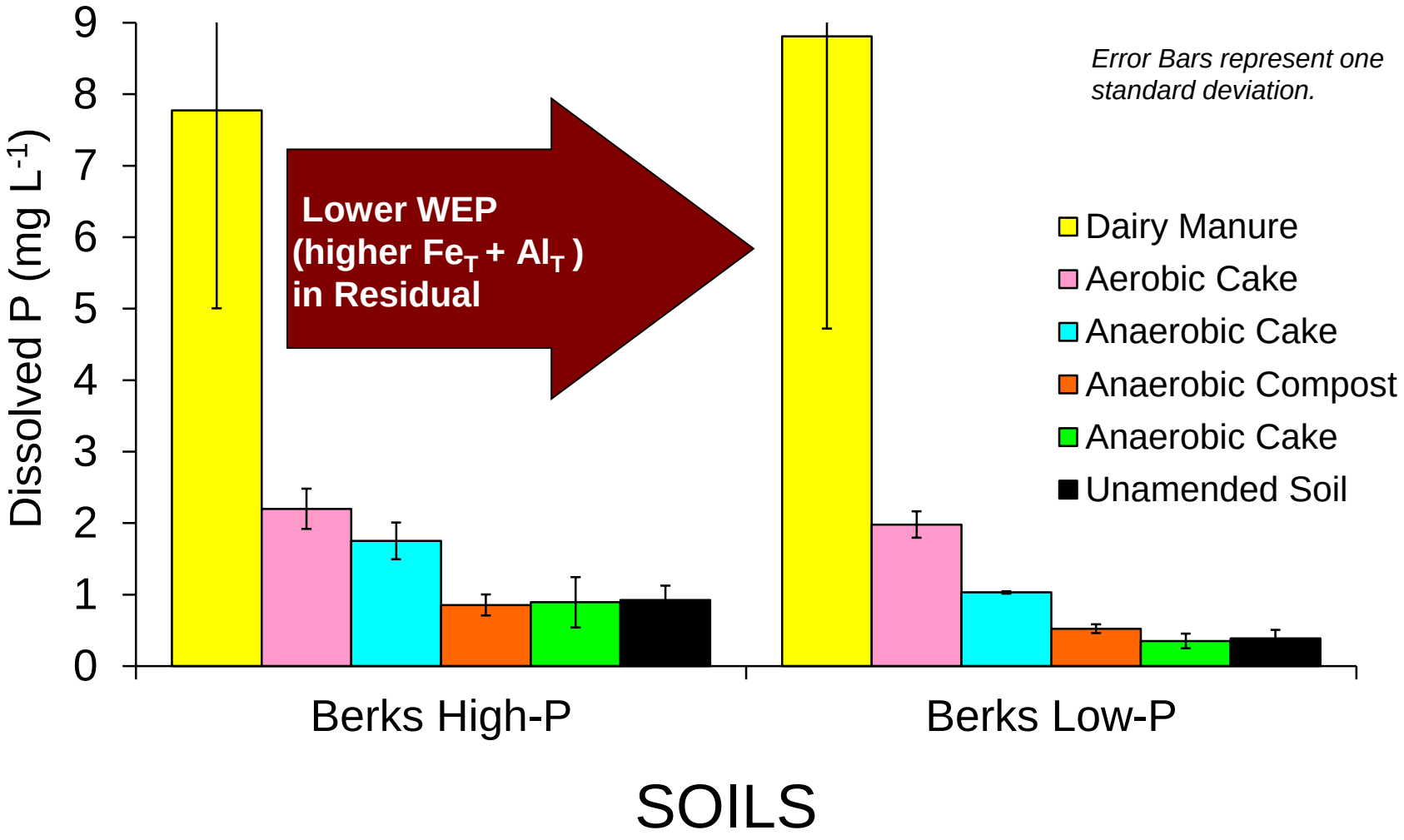
1. Total P content is a poor measure of environmental P loss potential.
2. The environmentally relevant portion of organic amendments is quantified by water extractable P (WEP) content.

Source P Solubility



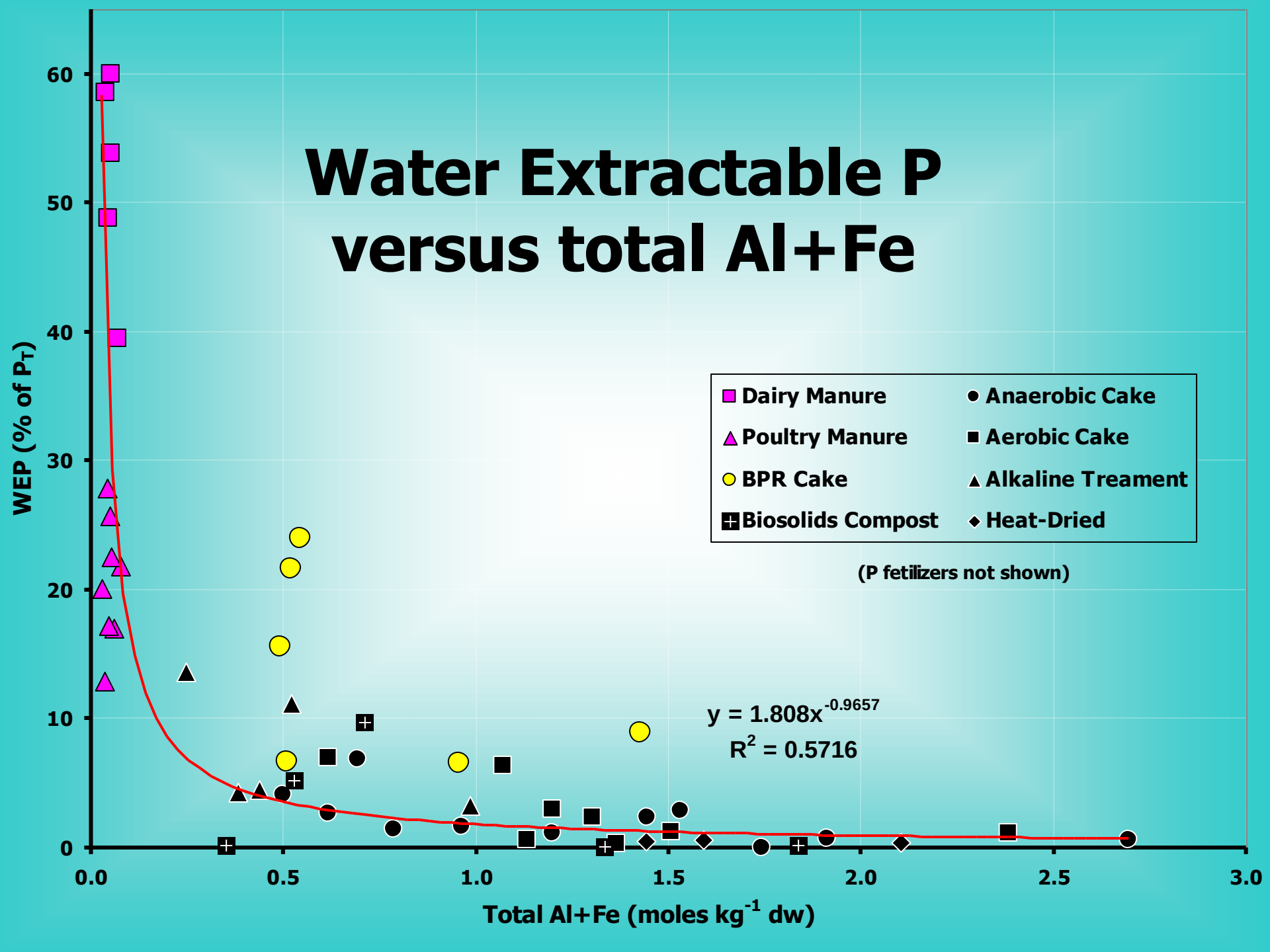
Runoff P from Surface-Applied Residuals

(all materials applied at 112 kg ha^{-1} Total P)



While WEP depends on various factors (livestock type, diet, storage, handling, treatment)….

Content of aluminum (Al) and iron (Fe) is of overriding importance.


Water Extractable P versus total Al+Fe
WEP (% of P_T)
Total Al+Fe (moles kg^{-1} dw)
0
10
20
30
40
50
60
0.0
0.5
1.0
1.5
2.0
2.5
3.0
Dairy Manure
Poultry Manure
BPR Cake
Biosolids Compost
Anaerobic Cake
Aerobic Cake
Alkaline Treament
Heat-Dried
(P fetilizers not shown)
$y = 1.808x^{-0.9657}$
$R^2 = 0.5716$

For a specific land-applied material, the key determinant is the relative amounts of P and Al/Fe:

Phosphorus Saturation Index:

$$PSI = \frac{P}{(Al + Fe)}$$

(with P, Al, Fe expressed on molar basis)

PSI for Amendments

material	P (g/kg)	Al(g/kg)	Fe(g/kg)	PSI (molar basis)
Dairy manure (PA)	7.06	0.45	0.74	7.62
Poultry litter (DE)	18.9	1.5	3.4	5.62
Alum-treated Poultry Litter (AR)	18.9	18.7	1.72	0.84
DC Water biosolids	30.4	4.0	88.0	0.57
Hampton Roads (VA) biosolids	30.1	13.7	56.0	0.64

States in the Bay Watershed (DE, MD, PA, VA) account for the variable P release potential of land-applied fertilizers/manures/biosolids in their P indices using P source coefficients (PSCs).

A P source coefficient (PSC) quantifies the environmental availability of a P source relative to inorganic P fertilizer (PSC = 1.0).

Tabulated PSCs
(Virginia P Index)

P Source	PSC
Mineral Fertilizer	1.0
Dairy/beef/poultry manures, BPR-biosolids	0.8
Alum-treated Poultry manure	0.4
Biosolids (non-BPR)	0.4

These PSCs are directly related to the WEP of the manure/biosolids:

For example, in the current MD P index (UM-PMT):

$$PSC = 0.117 \times WEP$$

The sizable differences in P loss potential of fertilizers, manures, biosolids need to be reflected in the edge-of-field load calculations.

The APLE Model

The APLE (Annual P Load Estimator) sub-model is a field-scale P loss quantification tool. Estimates annual P loss (lbs./acre) associated with sediment P loss, soil dissolved P loss, manure dissolved P loss, and Mehlich-3 P.

Allows manure WEP as input parameter.

APLE Model 10-Year Scenarios

- Used typical dairy manure composition
- Dairy manure spring application to supply 150 lbs. PAN per acre (typical N need for corn grain)
- Loading rates: surface (50.7 wet tons/acre) or incorporated (31.4 wet tons/acre)

APLE Model WEP Sensitivity Run (Dairy Manure Surface Applied)

Reduced WEP to simulate alum-amended manure. ↓

P loss (lbs/ac)	WEP = 50% (default value)	WEP = 5%
Sediment P	3.93	4.02
Soil Dissolved P	0.42	0.44
Manure Dissolved P	4.21	1.69 ↓
Total P loss	8.56	6.15 ↓
Mehlich3-P (after 10 yrs)	152	162

Lowering WEP significantly lowers Manure Dissolved P (and Total P) losses but modestly increases Sediment P and M3-P.

APLE Model Run (Dairy Manure Incorporated)

Double Application Rate

P loss (lbs/ac)	31.4 wet tons/acre	62.8 wet tons/acre
Sediment P	2.92	4.60 ↑
Soil Dissolved P	0.18	0.58
Manure Dissolved P**	0.00	0.00
Total P loss	3.11	5.19
Mehlich3-P (after 10 yrs)	57	227 ↑

Model relatively insensitive to input source beyond impact on total soil P (Sediment P) and M3-P

** "The model estimates the amount of dissolved manure P loss in runoff from the manure WEP on the soil *surface*."

Addressing Variable WEP Amendments

- Add sensitivity to WEP for Phase 6 (now)
- Add post-process BMP for Phase 6 (later)
- Modify APLE model

Add post-process BMP

Post-Process BMP

- BMP adoption document includes practice of adding alum to poultry litter to reduce ammonia emissions (p. 30, Simpson and Weammert, 2009)

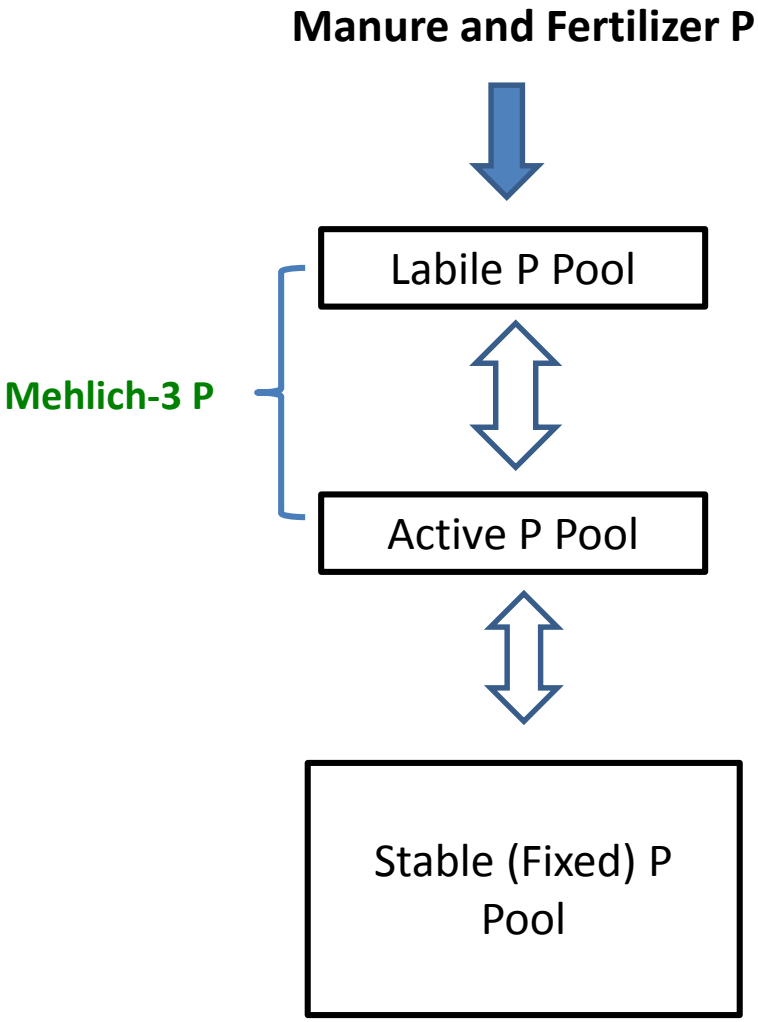
- Reduced runoff and leaching of soluble P listed as co-benefit of this practice (but no effectiveness estimate provided).

Add Post-Process BMP

- Develop BMP effectiveness estimates for amendments inherently elevated in Al/Fe content (biosolids) or through intentional modification (chemically treated manures).
- Such a BMP has been developed by the SERA-17 group.

Modify APLE method of P addition

Current APLE Model Distribution of Added P



"All added P initially added to the Labile P pool"

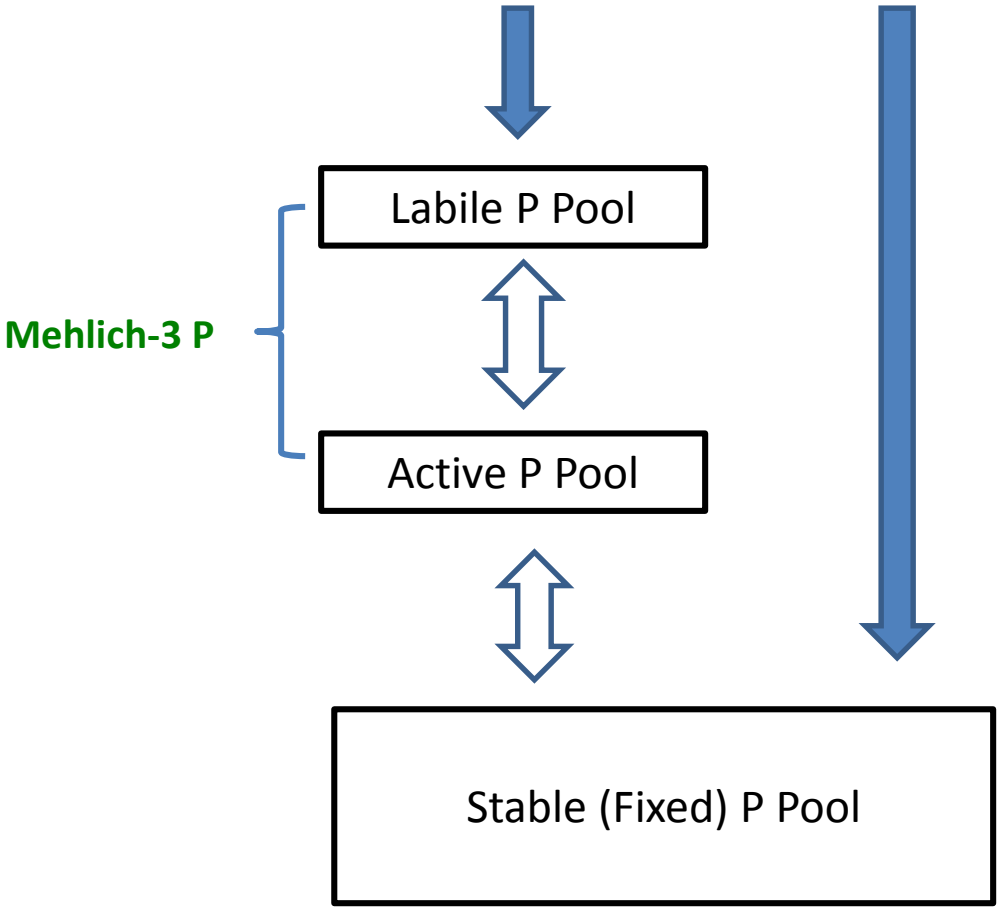
Rapid equilibrium with Active P
K = 0.1 d^{-1} ($t_{1/2}$ = 6.93 days)

Slow equilibrium with Stable P
K = ~0.0005 d^{-1} ($t_{1/2}$ = 1386 days)

Result: Slow buildup of Stable P from added amendments

Possible Alternative Distribution of Added P

Biosolids and Chemically Treated Manure P



Added P initially put in Labile P and Stable P pools

Add sensitivity to WEP for Phase 6