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Development of Regionally-Consistent Phosphorus Source Coefficients for Use in Phosphorus Index Evaluations in the Mid-Atlantic Region

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The Phosphorus Index

The Phosphorus Index (PI) was designed as a screening tool for use by soil conservation field staff and nutrient management planners to rank the relative vulnerability of agricultural fields as sources of phosphorus (P) loss in surface runoff water. The PI uses readily available information to evaluate two broad categories of factors that contribute to the potential for P loss from agricultural land: 1) P loss potential due to physical characteristics of the site and the potential for off-field transport of P with field drainage water, and 2) P loss potential due to field management practices and characteristics of the P source.

Regional Uniformity

Although conceptually consistent, development of PIs in the Mid-Atlantic Region has yielded state-specific versions that differ in specific content and numeric calculation. However, each state PI incorporates a measure of P solubility or relative availability of P in land-applied nutrient amendments. Our goal was to reach regional consensus on a common approach and process for incorporating P solubility information into state-specific PI determinations.

Phosphorus Source Coefficients

One of the evaluation factors used to assess a site's P loss potential is a measure of the P solubility of nutrient materials applied to the soil. The Phosphorus Source Coefficient (PSC) represents the relative proportion of the total P applied to the field that is potentially subject to loss with drainage water. The PSC is a quantifiable characteristic of the nutrient amendment and is independent of the characteristics of the soil to which the amendment is applied. In practice, PSCs either can be defined for various categories of land applied nutrient amendments or determined for specific materials by standard laboratory procedures. In some situations, defined "book values" may provide an adequate estimate of the PSC while, in other situations, use of a PSC determined for a specific amendment material may be preferable.

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Reaching Consensus

In June 2004, the first of a series of Mid-Atlantic Regional meetings was convened with the goal of improving the regional consistency of the PI site evaluation tools currently in use. The objective of the meeting was to reach consensus on the definition and use of PSCs for describing various land applied P-containing materials including fertilizers, manures, and biosolids. After review of available data, our objective was met and consensus Mid-Atlantic PSC values were adopted by all states in the region for five categories of nutrient amendments. **Table 1** presents the regionally-consistent PSCs, expressed on a relative scale from zero to 1.0. Application of regional PSC values to respective state's PI calculations will necessitate the use of different absolute numeric values from state to state, but agreed-upon relative PSC values will be preserved regionally.

Table 1. Mid-Atlantic Region P Source Coefficients (PSC) for use in P Index site evaluations.

P Source	PSC
Inorganic P fertilizer	1.0
Swine manure	1.0
Other manures (beef, dairy, poultry, etc.)	0.8
BPR & BNR biosolids	0.8
Alum-treated manures	0.5
Biosolids (all except BPR & BNR)	0.4

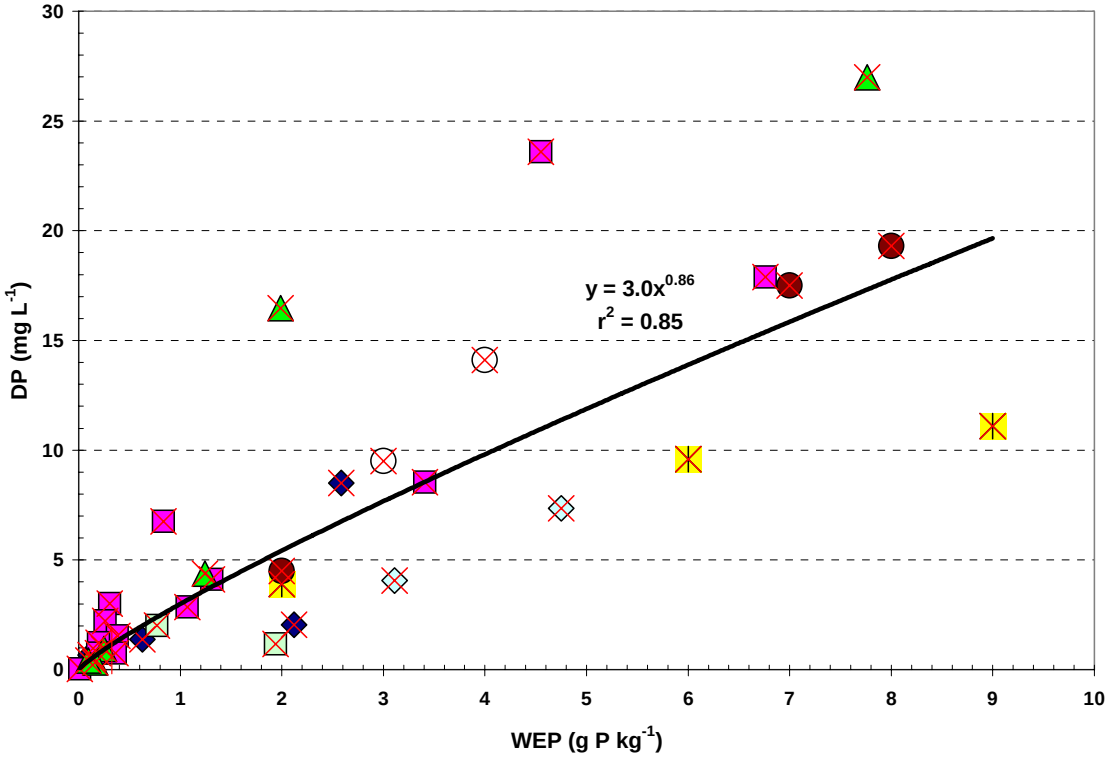
Determining PSC Values

Frequently, conservation or nutrient management planners do not wish to rely on the average value or "book value" definitions for the PSC of a specific nutrient amendment that is to be land-applied. In such cases, it is necessary that a uniform procedure be followed for determining the relative P solubility of the specific nutrient source. Several studies have indicated that the P loss potential following land application is related to the water solubility of the applied P source. In **Figure 1** we illustrates the relationship between dissolved P (DP) in surface runoff water and water-extractable P (WEP) of the land-applied nutrient amendment for eight rainfall simulation studies. For all studies, the P source was surface applied and not incorporated into the soil. Runoff DP was measured in the first runoff event following amendment application. The total P loading rates (kg P ha^{-1}) and detailed procedures for determining WEP varied among the eight studies. Evaluation of these data indicated that WEP of a surface-applied nutrient amendment material was a reliable predictor of subsequent DP concentration in surface runoff.

PSC versus WEP

Several defining parameters were imposed in order to develop a regionally consistent relationship between PSC for use in PI determinations and measured WEP of a nutrient amendment. First, a minimum PSC = 0.1 was established. Thus, even for land-applied organic materials with zero or near zero water soluble P concentration, a positive contribution to the P-source component of the PI assessment was retained.

Figure 1. Runoff DP versus amendment WEP for eight rainfall studies

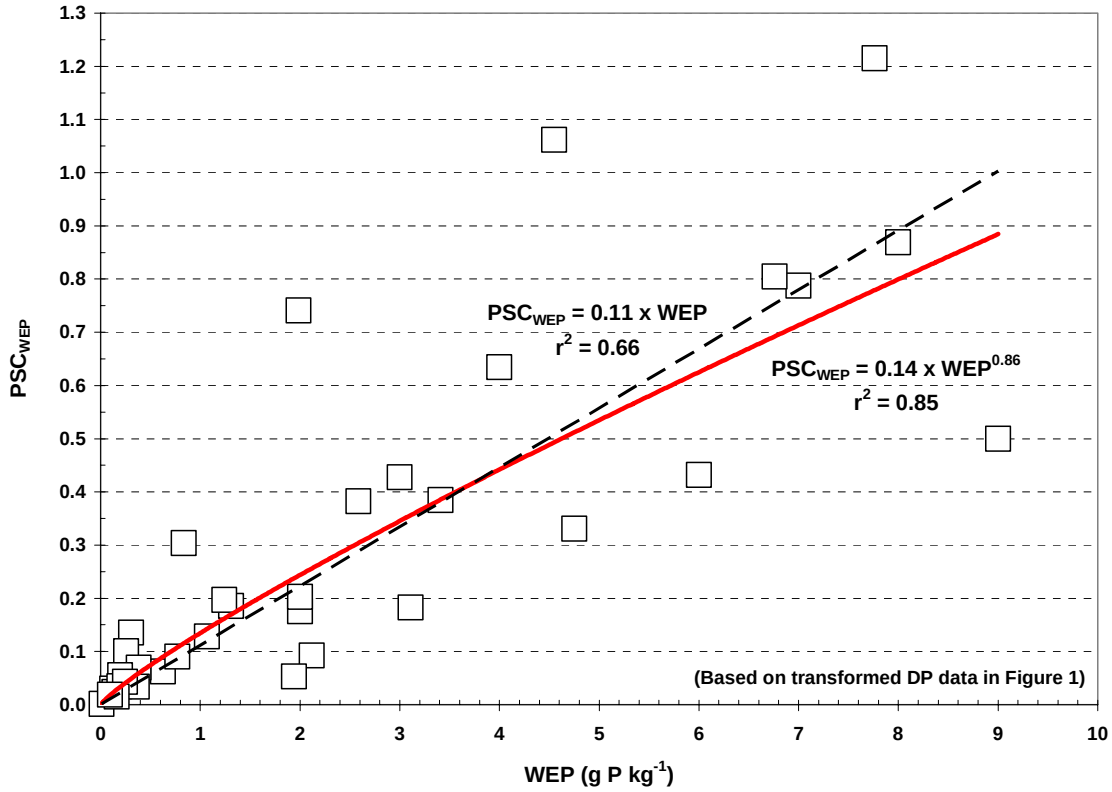


Second, evaluation of manure P analyses for different animal species disclosed that swine slurry had the greatest median WEP (9 g P kg^{-1}). The PSC for swine slurry was considered to be equivalent to the PSC for inorganic commercial fertilizer P and was defined as PSC = 1.0. Furthermore, all land-applied nutrient amendments with WEP concentrations greater than 9 g P kg^{-1} were defined to have PSC = 1.0. In **Figure 2**, we present the relationship between PSC determined from WEP (PSC_{WEP}) and WEP. The maximum PSC was assigned to land-applied nutrient materials that had WEP = 9 g P kg^{-1}, or greater. Applying the power function from Figure 2 resulted in PSC_{WEP} values ranging from zero to 0.9. After adjusting for the defined minimum PSC = 0.1, PSC determination from WEP was established:

$$\mathbf{PSC = 0.1 + PSC_{WEP} = 0.1 + 0.14 \times WEP^{0.86}.} \quad \text{(Eq. 1)}$$

The linear relationship between PSC_{WEP} and WEP is shown in Figure 2 as an example of a more simplistic description of the PSC-WEP relationship. The linear relation suggests that PSC may be approximated as 11% of determined WEP. However, this more simplistic approximation greatly overestimated PSC for amendments with relatively high WEP concentrations. Regionally, the power-function relationship shown above in Eq. 1 was adopted for PSC determination from WEP. As with the generalized PSC values in presented in Table 1, application of PSC values determined from measured amendment WEP concentration will necessitate the use of different absolute numeric values from state to state, but relative PSC values will be preserved regionally.

Figure 2. PSC_{WEP} versus Amendent WEP



Summary

Our goal was to reach regional consensus on a common approach and process for incorporating P solubility information for land-applied nutrient amendments into state-specific PI determinations. Consensus Mid-Atlantic PSC default values were adopted by all states in the region for five broad categories of nutrient amendments. The regional workgroup determined that WEP of a surface-applied nutrient amendment material was a reliable predictor of subsequent DP concentration in surface runoff. We used this information to define a process for determining the PSC of a specific nutrient amendment from the measured WEP of the amendment material. Therefore, nutrient management planners may utilize either the default PSC "book values" presented or use the process defined for determining PSC from measured WEP to consistently ascribe the impact of the P solubility of different land-applied amendments in phosphorus index determinations of the potential for P loss in field drainage water in the Mid-Atlantic region.

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