Orthophosphate and Phytate Extraction Differences by Common Tests Used for Soil Phosphorus Evaluation from Soil Mineral Components

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Introduction

Chemically extractable P has been widely used for P environmental assessment because of its strong relationship with P loss through surface runoff and/or subsurface leaching. The application includes predicting P concentration and amount of P available to runoff and leaching, and estimating the degree of P saturation (DPS). Orthophosphate (Pi) and myo-inositol hexakisphosphate (phytate or IHP) differ significantly in adsorption capacity and chemical affinity to soil surfaces; and we predict that these differences may strongly influence the outcomes obtained by chemical extraction of P, and thus possibly the parameters used in P environmental assessment. In this study, five common extractants (water, 0.01M calcium chloride, Mehlich 1, Mehlich 3 and acidified ammonium oxalate in darkness (AOD) were used to recover two major P forms (Pi and IHP) that were adsorbed at various P saturation levels on Na-saturated goethite, gibbsite, kaolinite and montmorillonite. The purpose of the study was to evaluate how these P forms and mineral types influence the efficiency of these extractants to solubilize P and to examine the inter-correlations between extractable P forms.

Experimental

Adsorption: Mineral conc. = 1%; initial P conc. = 0 – 80 µg mL^{-1}; equilibration time = 24 h; centrifugation at 8k to 14k g for 10 min for solid/liquid separation; duplicates.

Extraction: Freeze-dried phosphated minerals at P levels of 0-100% of Langmuir adsorption max. were prepared. 200 mg P-clay/sample for extraction; duplicates.

Water – 10 mL, 1 h extraction;
0.01M CaCl$_2$ – 10 mL, 1 h extraction;
M1 – 20 mL, 5 min. extraction;
M3 – 10 mL, 5 min. extraction;
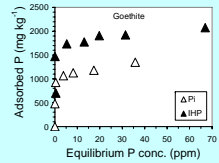AOD – 20 mL, 2 h extraction in darkness.

Results

Fig. 1. Adsorption isotherm for phosphates on goethite (example mineral). These results were fitted to the Langmuir equation and the related parameters are given in Table 1.

Table 1. Langmuir isotherms§ for adsorption of Pi and IHP on mineral surfaces.

Minerals	Pi			IHP		
	b	K	r^2	b	K	r^2
Goethite	1538	0.445	0.9972	1818	2.500	0.9997
Gibbsite	196	3.643	0.9963	294	11.333	0.9999
Kaolinite	294	0.919	0.9951	1250	4.000	0.9989
Montmorillonite	137	0.117	0.9853	227	2.000	0.9941

§: b = Langmuir adsorption maximum; K = a constant related to binding energy; r = linear regression coefficient.

Goethite   Gibbsite   Kaolinite   Montmorillonite

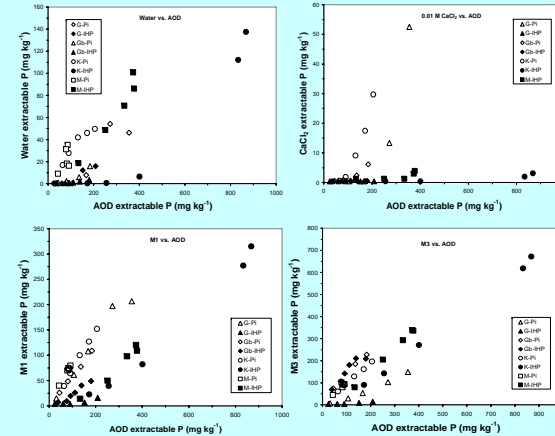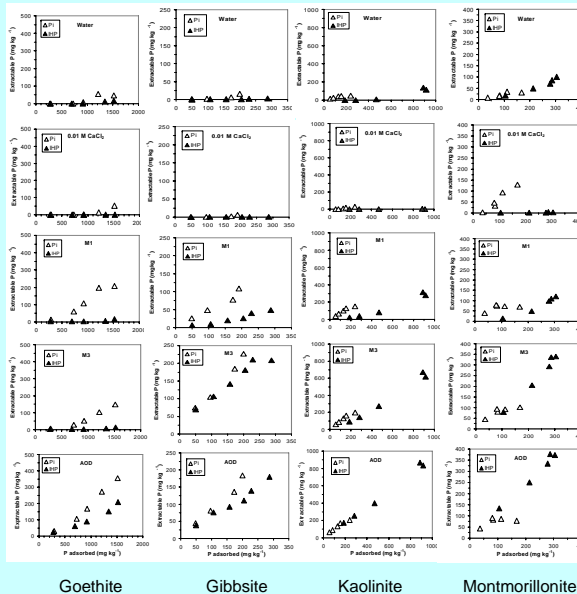Fig. 2. Amounts of P extracted by five extractants from phosphated minerals.

Fig. 3. M3-P produces the closest prediction of AOD-P; weaker extractants failed to account for the difference in P forms.
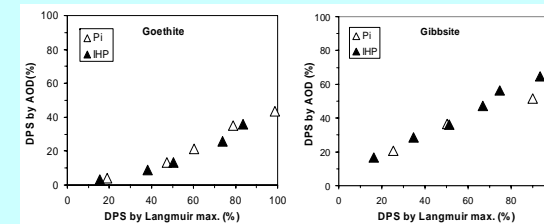

Fig. 4. The relationship between the DPS calculated from AOD extraction and from the Langmuir adsorption maximum for metal oxides does not vary with P forms but does with goethite and gibbsite minerals. The DPS by AOD does not apply to Na-saturated kaolinite and montmorillonite.

Note:

DPS (%) by AOD = $P_{AOD}/[0.5 \times (Al_{AOD} + Fe_{AOD})] \times 100$

DPS (%) by Langmuir max.= $P_{ads}/$Langmuir max. $\times 100$

Discussion and Conclusions

1. Phytate has a substantially greater Langmuir adsorption maximum than Pi for all minerals.

2. Phytate has a lower solubility in all extractants. Water and 0.01M CaCl$_2$ extracted negligible IHP from all minerals.

3. The lowest P extractability were found with goethite, followed by gibbsite < kaolinite < montmorillonite.

4. Mehlich 1 was less efficient than Mehlich 3 and AOD, which are equivalent in terms of the amount of P extracted.

5. At similar levels of AOD-extracted P, extracted Pi by Mehlich 1 is greater than extracted IHP for all minerals (Fig. 3).

6. At similar levels of AOD- extracted P, extracted Pi by Mehlich 3 from goethite is less than extracted IHP from the remaining minerals.

7. DPS obtained by the AOD method is mineral-type dependent suggesting that it may also be a soil dependent quantity. It is not applicable in non-Fe and –Al solid phases.

Acknowledgements

References

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