Behavior of Organic Sources of Phosphorus in Agricultural Systems

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Plant Available Phosphorus

- Inorganic orthophosphates
  - $H_2PO_4^-$
  - HPO_4^{2-}

Organic Phosphorus

- Surface Soils (75% of Total P)
- Average C:N:P ratio 140:10:1.3)
  - C:P range
    - 67 -311:1 Virgin Soils
    - 141-526:1 Cultivated Soils

Factors Influencing C:P Ratio

- P Supply
- Parent Materials
- Texture
- Climate
- pH
- Depth of Soil

Mineralization of Organic P

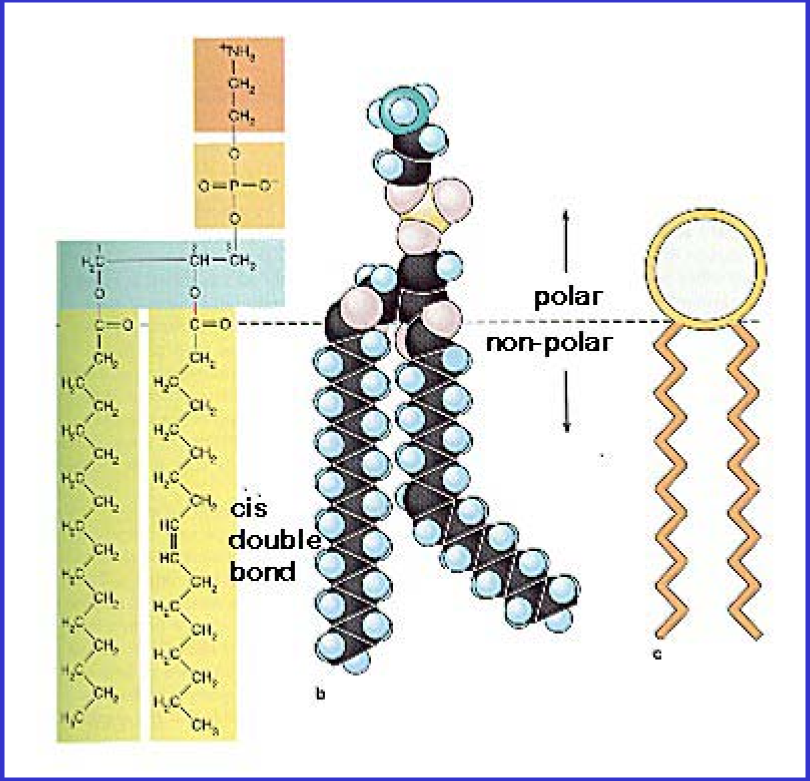
- Organic P → Inorganic P
- C:P <200 Mineralization (P gain)
- C:P 200 -300 No Change
- C:P >300 Immobilization (P loss)

Factors Controlling Mineralization of P

- Chemical form of organic P
- pH
- Temperature
- Soil Moisture
- Soil Microbial Communities
- Soil Enzymes

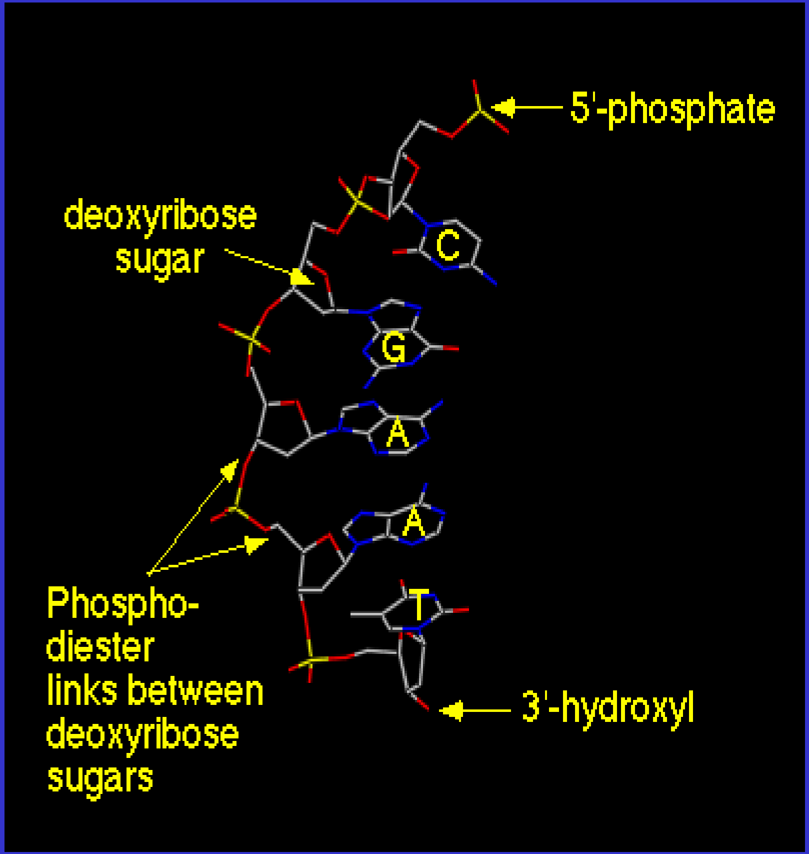
Phospholipids

- Parts of Cell Membranes
- Ill defined Group
- Estimates 1-3% of Soil Organic Matter
- Underestimated
- Strongly associated with soil mineral fractions



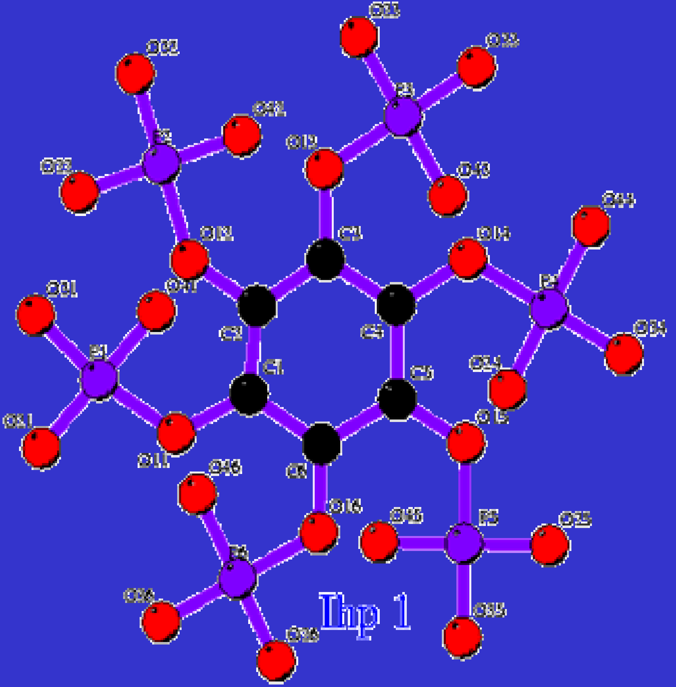
Nucleic Acids

- Present in all Cells
- Backbone of Nucleic acids
- Easily Decomposed
- Less than 3% of Soil Organic Phosphorus

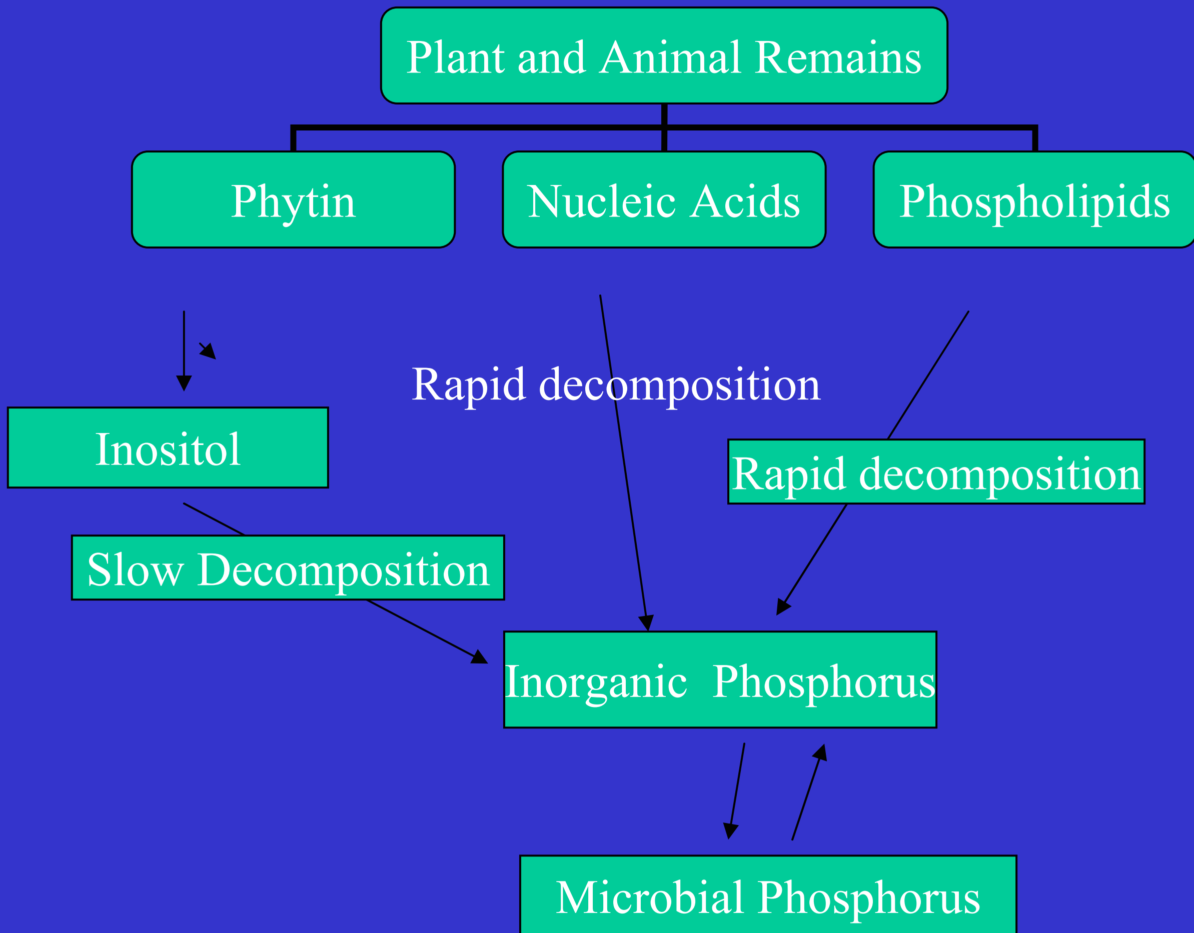


Phytic Acid (Inositol Hexaphosphate)

- Mixed with Ca
- Cereal Grains
- Insoluble complexes
- Slow Decomposition
- High Stability
- Limited Phytase in Soils
- Synthesized in Soils



Mineralization of Organic Phosphorus



Distribution of Inositol P in Soils

Form	% of Soil Organic P	Percentage of IP
Mono	1 -6	1-11
Di and Tri	4-11	6-15
Tetra	5-18	8-30
Penta	15-27	15-30
Hexa	20-66	20-66

Recovery of Organic P

Soil	Organic P ppm	IHP %	Phospholipids %	Nucleic Acids%	Total %
1	39	44	7	2	54
2	187	66	2	0.2	68
3	250	60	1	0.5	61

Water Soluble Organic P

P form	P Faction mg/kg	%
Total Organic P	779	100
Monoester P	55	7
Inositol P	302	40
Nucleic Acids	43	6
Unreleased	377	48

$NaHCO_3$ Extractable Organic P in Manure

P form	P Faction	%
Total Organic P	426	100
Monoester P	1	3
Inositol P	14	3
Nucleic Acids	5	1.1
Unreleased	48	86

Mode Of Organic P Loss

- Two forms: soluble P and particulate P.
  - Soluble P:
    - Inositol hexaphosphate
    - Subsurface flow in tile drainage systems;
    - Not directly available to algae.

Modes Of P Loss (Contd.)

- Particulate P (Sediment P):
  - rides fine-sized particles;
  - less available;
  - forms better part of total P loss.

Lack Of Control Of Dissolved P

- Most of the management practices, namely,

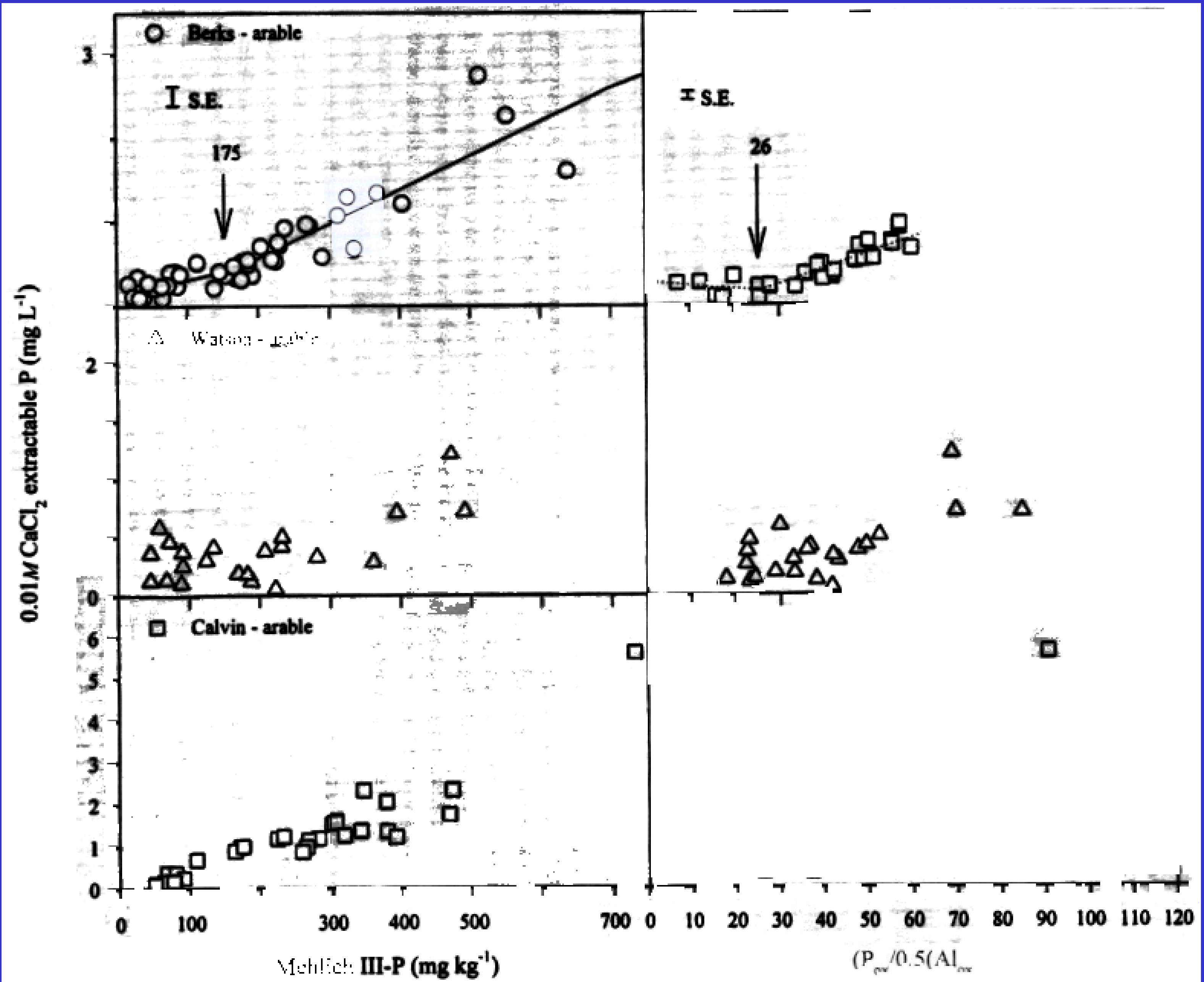
  riparian buffer strips, conservation tillage, terracing, contour plowing, impoundments, etc.,

  effective in controlling particulate P, but do not reduce soluble P levels adequately.

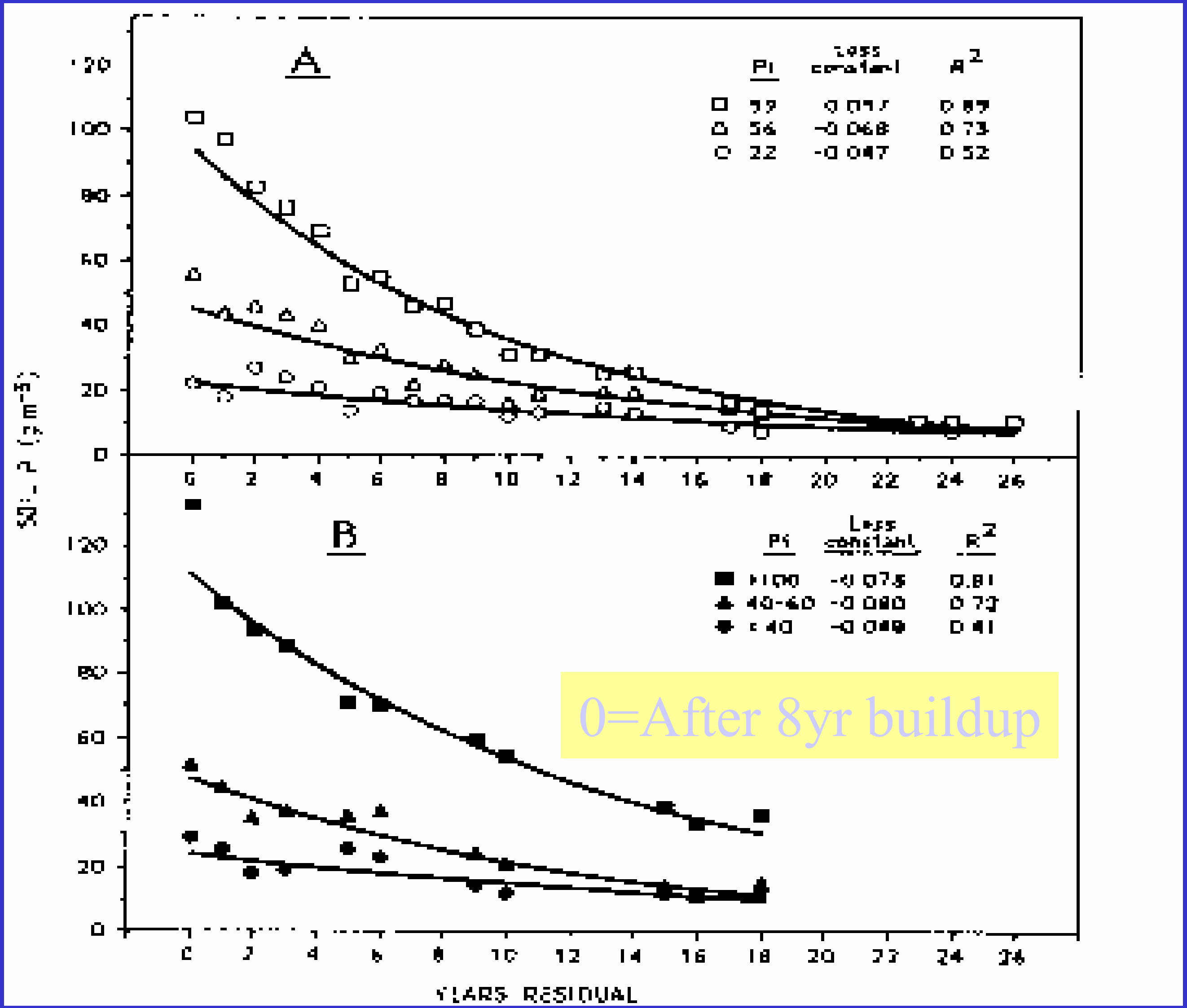
Loss Of Dissolved P:relation Between Soil Test P And Water Soluble P

- With increase in soil test P (STP), water soluble P(or the propensity of the soil to release P) in the runoff increases.
- Release explained by two linear relations of significantly different slopes on either side of a point, called change-point;

Change-point



Slow crop removal(McCollum,1991)



Crop removal of residual P doesn't have adequate effect

THEREFORE, NEED TO CONTROL DISSOLVED P

How ??

- **Reducing dissolved P content in manures.**
- **Increasing P sorption capacity(or decreasing degree of phosphorus saturation) of the soil or border strips.**

Iron And Aluminum Oxides

- Have great affinity for dissolved P.
- Several industrial and mining wastes are rich in these oxides.
- Acid mine drainage floc is one.

Use Of Industrial And Mining Wastes

- Peacock and Rimmer (2000) examined the suitability of an iron oxide-rich gypsum byproduct as a soil amendment.
- Red gypsum: a byproduct of titanium oxide pigment manufacturing industry; contains about 35% iron oxides.
- P sorption characteristics of red gypsum compared with those of pure gypsum and iron oxides isolated from the red gypsum.

So, other readily available iron oxide-rich mining wastes should be evaluated for their ability to attenuate P in runoff and leachates from soils

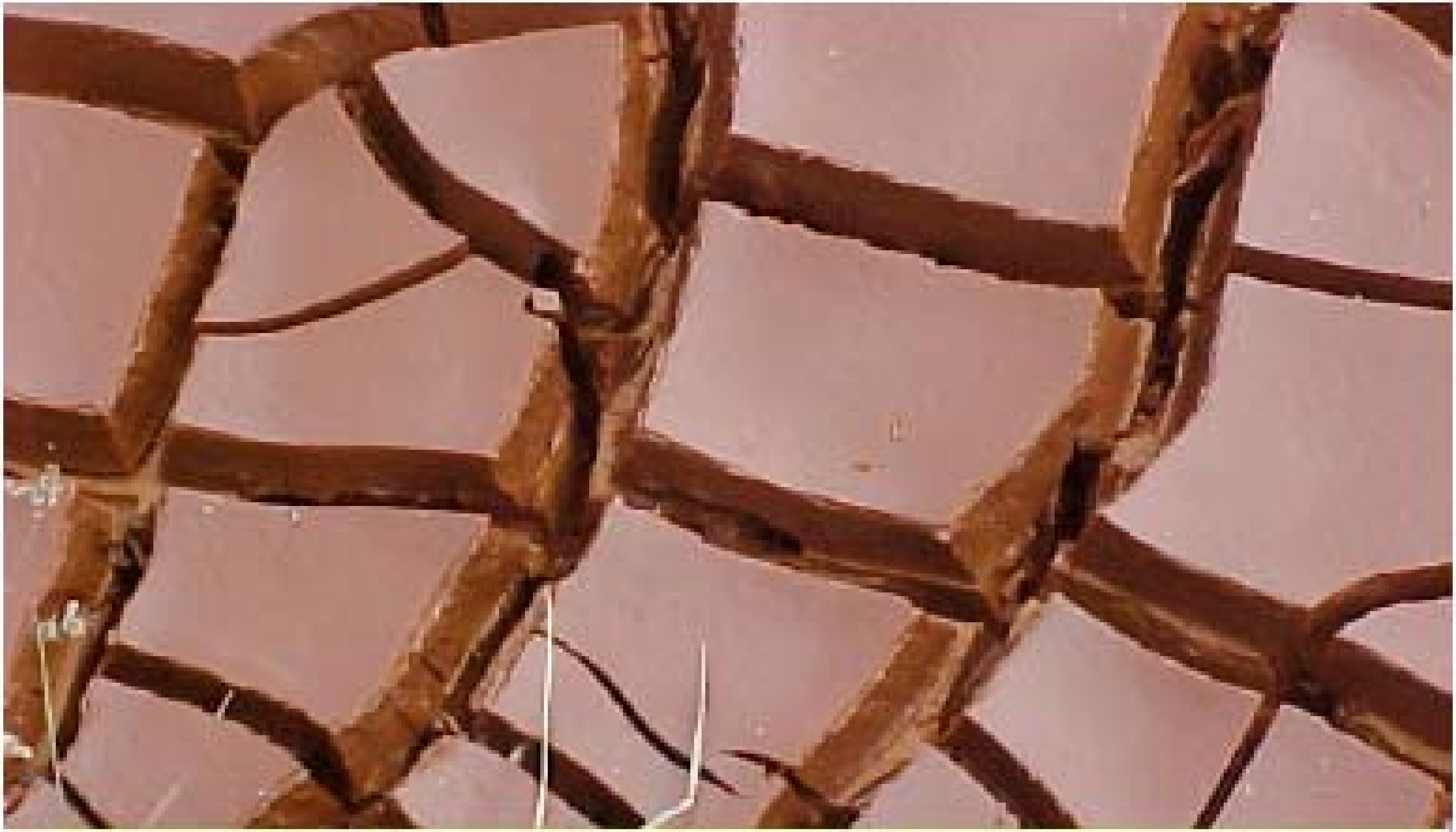


Fig. 2. Initial drying stage of acid mine drainage floc (5% solids)

Objectives

Study of effectiveness of border strips treated with acid mine drainage(AMD) floc in controlling runoff P loss; and

- Study of P sorption onto AMD floc.

Sorption of P onto acid mine drainage floc

- Objectives:
  - To assess P remediation potential of various AMD flocs.
  - To investigate implications of P sorption on various AMD flocs in determining environmental thresholds of P for soils in which amorphous Fe and Al oxides are the main controllers of P movement.

Materials and Methods

- AMD collected from Omega mine in Monongalia county of WV.
- One part of AMD collected and titrated at the site of discharge with 1.0M ammonium hydroxide to pH 7.
- Similarly, the other part titrated with 1.0M NaOH.
- The third type of floc was lime-treated.

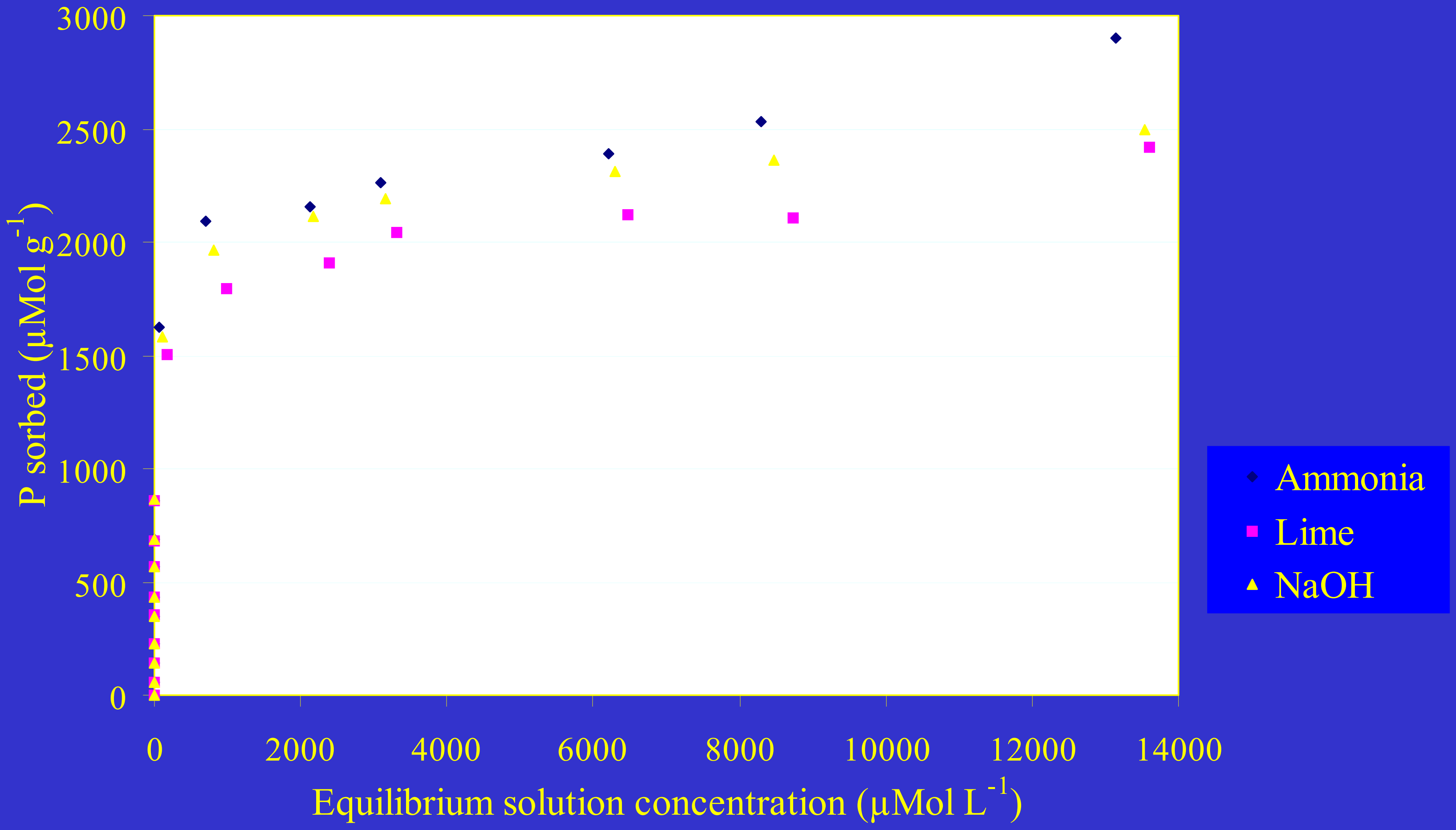
Materials and Methods (contd.)

- Similarly, another set equilibrated with inositol hexaphosphate (IHP)-P.
- Three replicates.
- Measurements for inorganic P, IHP-P and metals on ICP-AES.

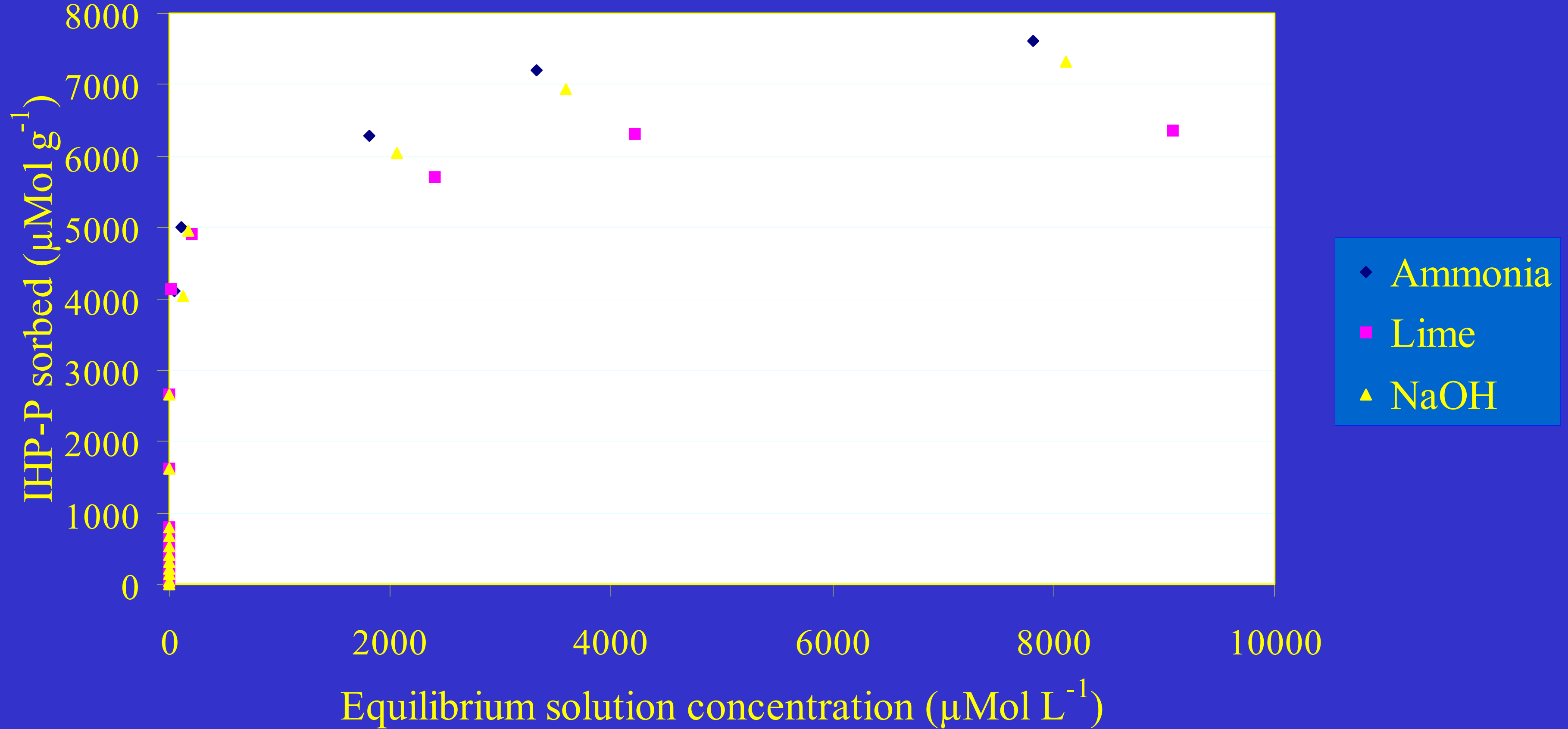
Elemental composition and P sorption capacity of the flocs

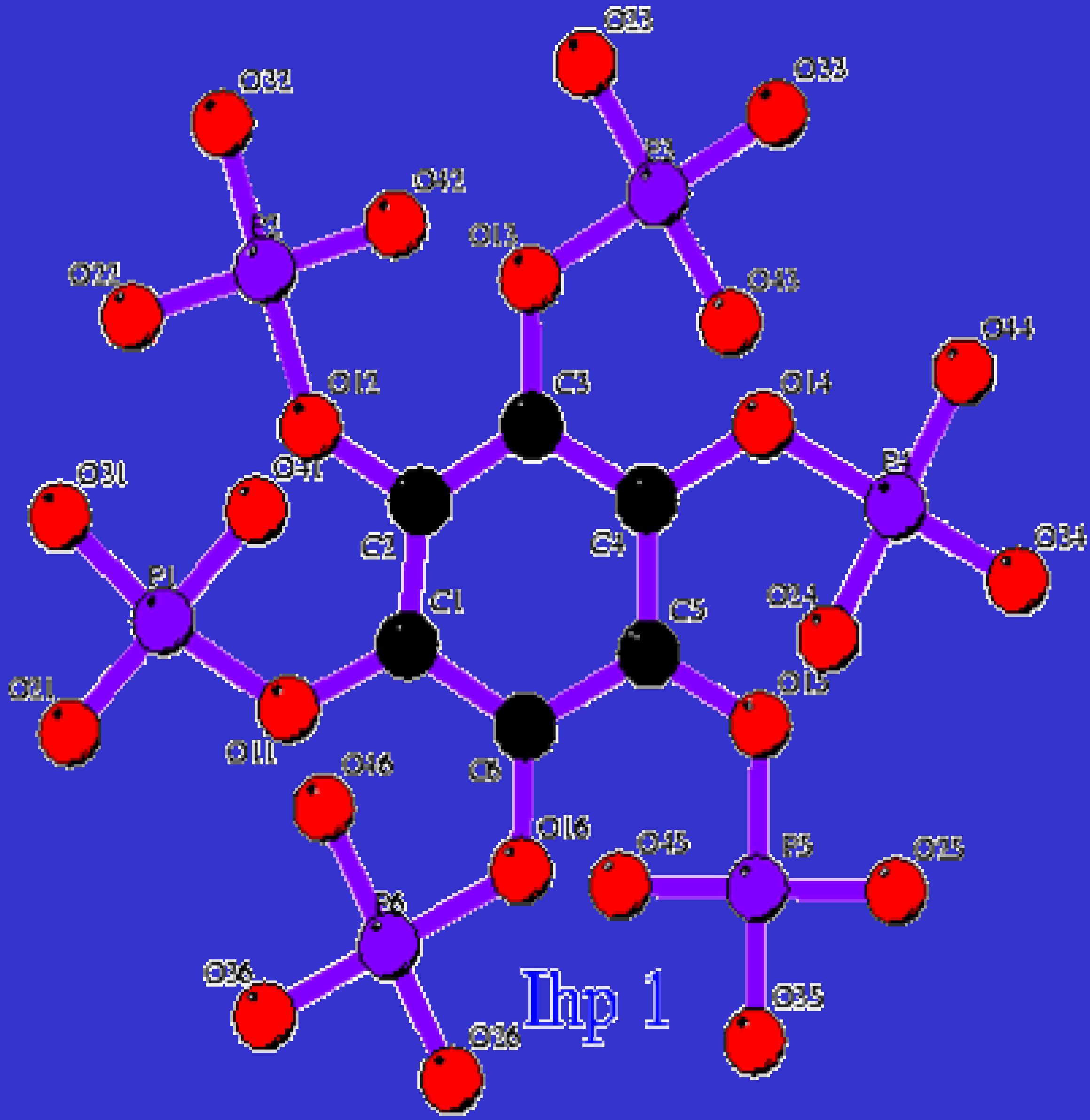
- >99% of total Fe amorphous.
- > 98% of total Al amorphous.

Sorption of inorganic-P on various acid mine drainage flocs

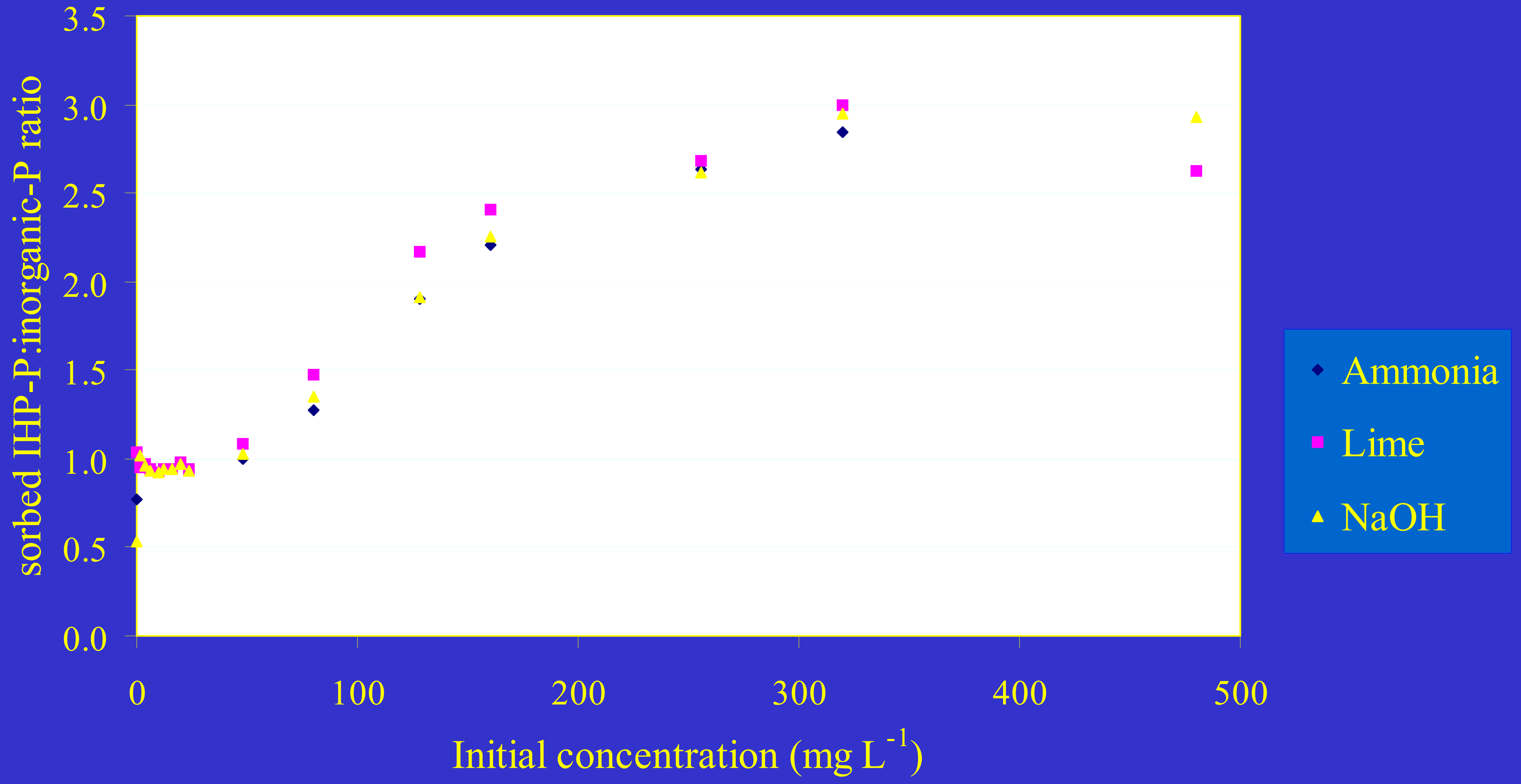


Sorption of inositol hexaphosphate (IHP)-P on various acid mine drainage flocs.




C1
C2
C3
C4
C5
C6
P1
O11
O12
O14
O15
O16
O21
O31
O32
O41
O42
O44
O45
O25
O35
Ihp 1

Ratio of inositol hexaphosphate (IHP)-P and inorganic P sorbed onto various acid mine drainage flocs.



Conclusions

- Various AMD flocs can sorb substantial amounts of P.
- Far greater amounts of IHP-P than inorganic-P sorbed.

Hydrolysis of inositol hexaphosphate (IHP) by AMD floc

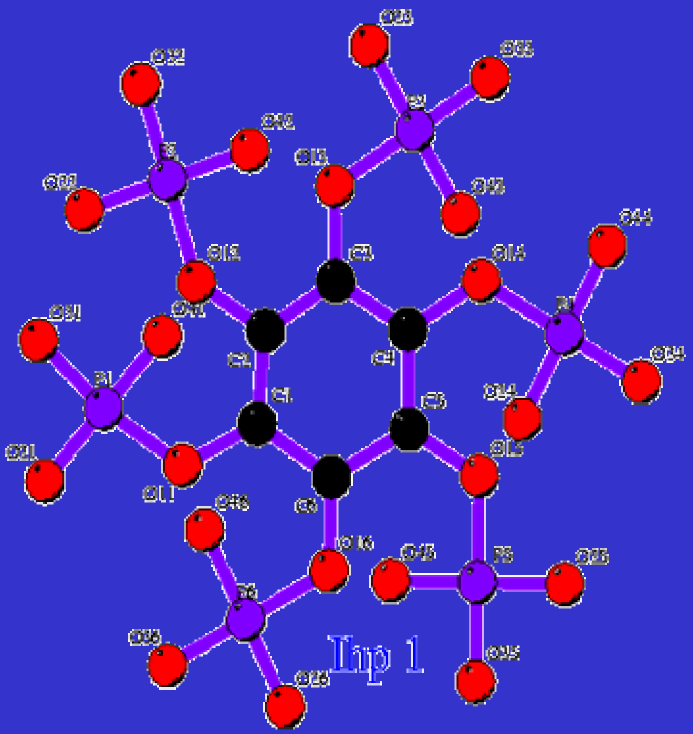
- Inositol hexaphosphate (IHP) or phytate sorbs strongly onto Fe and Al oxides.
- Some studies: metal oxides facilitate hydrolysis of organic compounds.

Consequences of hydrolysis

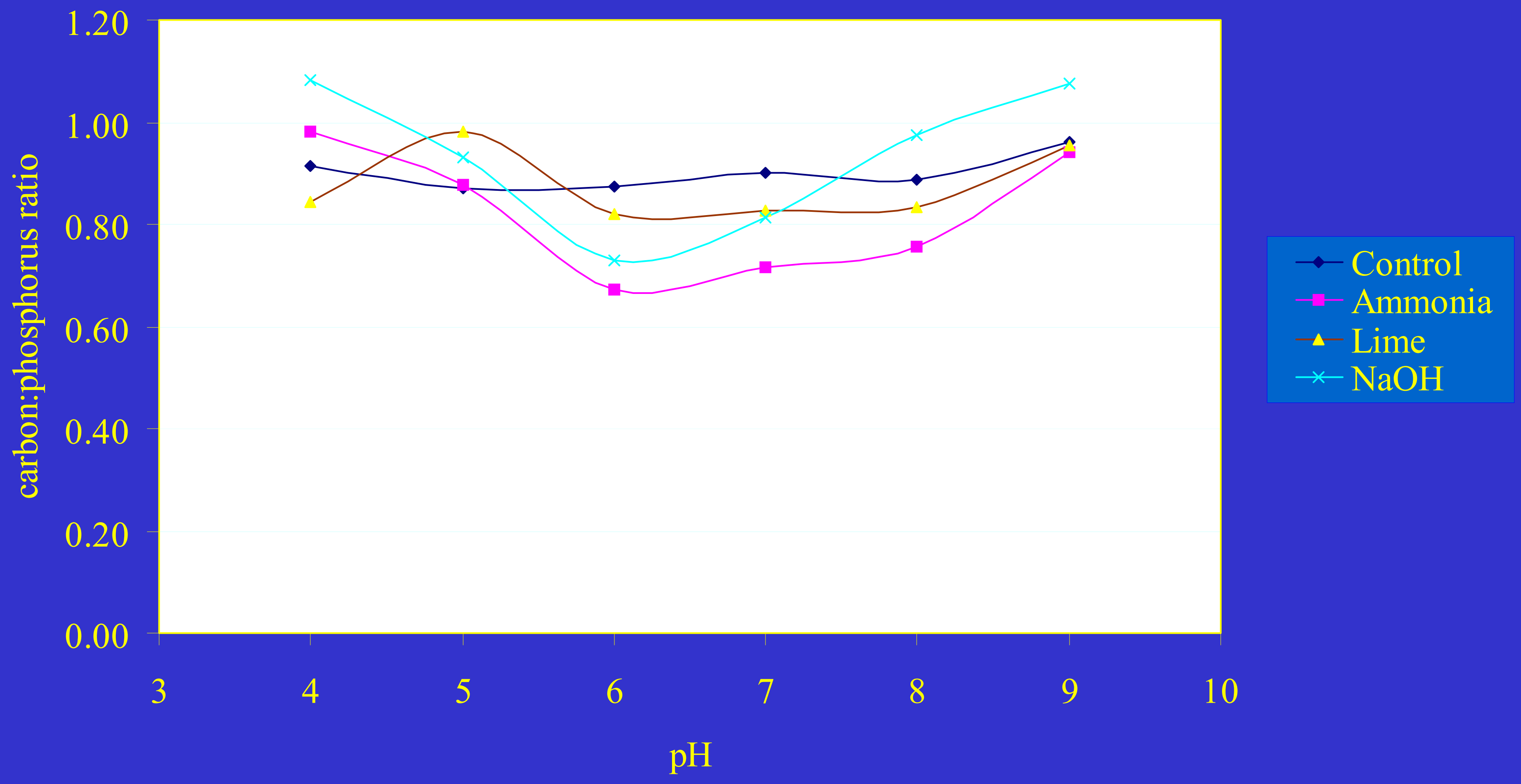
- Hypothesis: P retained, organic moiety released.
- Then, P attenuation capacity of flocs impaired.
- If IHP hydrolyzed first, P ions take more sites.

Diagnosis for hydrolysis

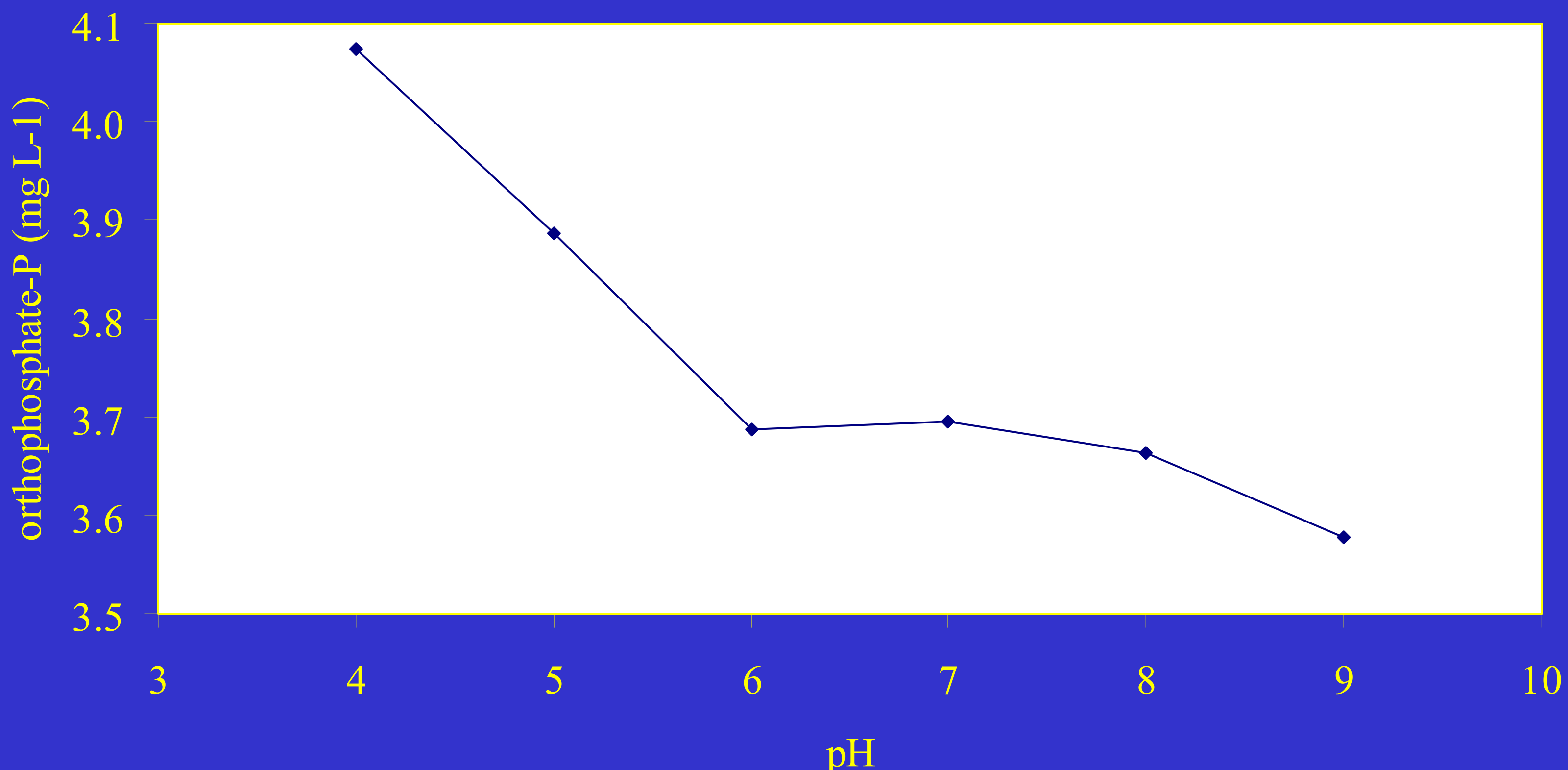
- Carbon: Phosphorus ratio in equilibrium solution (with AMD floc).
- If ratio more than that in blank, IHP-P sorbed after hydrolysis.
- If ratio same: sorbed as it is.



Carbon: Phosphorus ratio of IHP-P solutions equilibrated with or without AMD flocs.



Orthophosphate-P concentrations of 200mg L^{-1} IHP-P solution at various pH levels



Conclusions

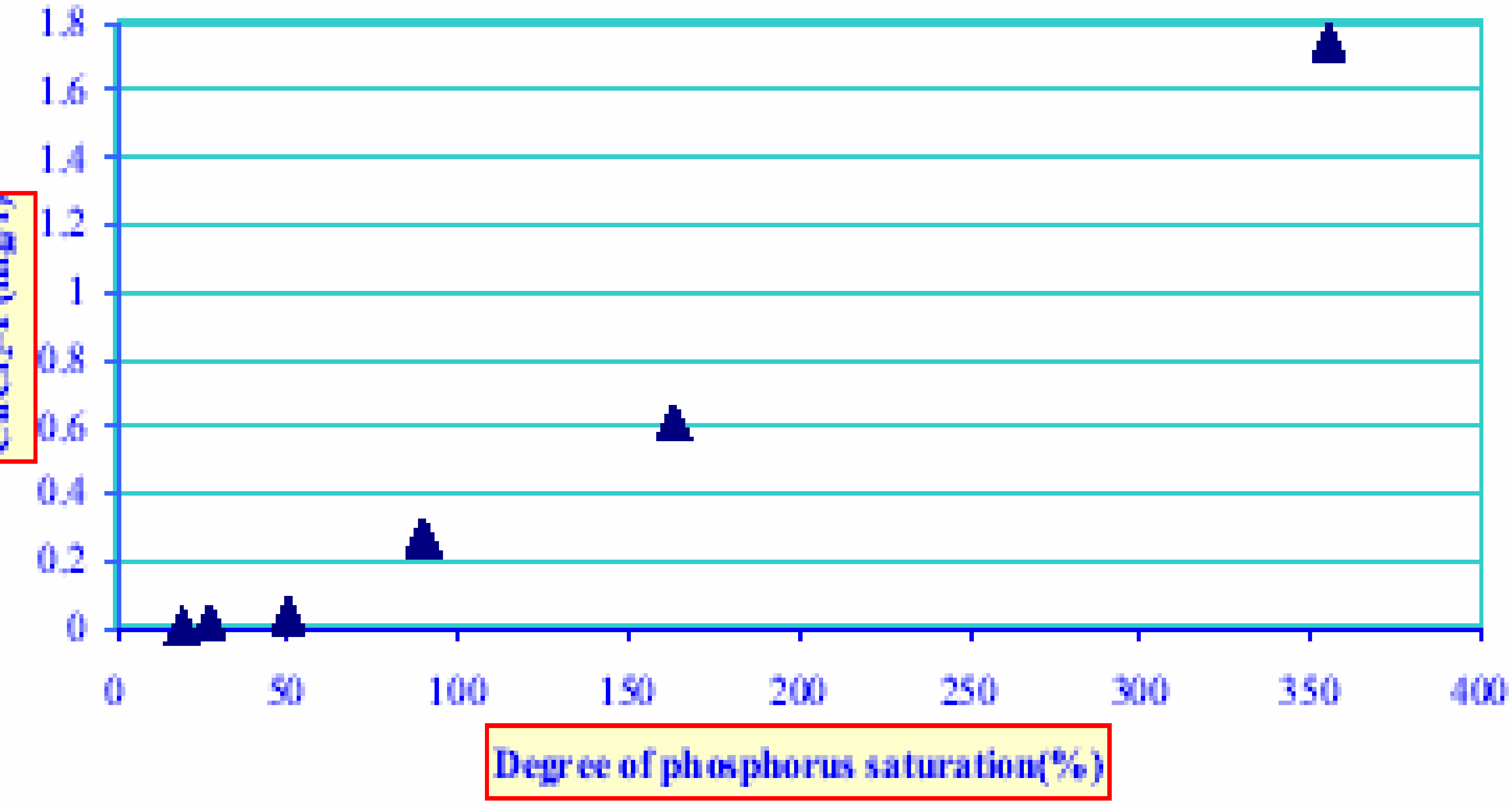
- IHP sorbed *as such*.
- No appreciable effect of pH.
- AMD floc attenuates much more IHP-P than inorganic P.

Effectiveness Of Border Strips Treated With AMD Floc In Controlling Runoff P Loss

- Rainfall simulation experiment:
  - runoff plots set up at three different locations in Grant and Pendleton counties (WV).
  - 0, 20, 40, and 60 per cent of the area covered by slurry of AMD floc.
  - USDA-ARS rainfall simulator.
  - Four rainfall events

Runoff Plots

Rainfall Simulator


1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0
50
100
150
200
250
300
350
400
Degree of phosphorus saturation(%)

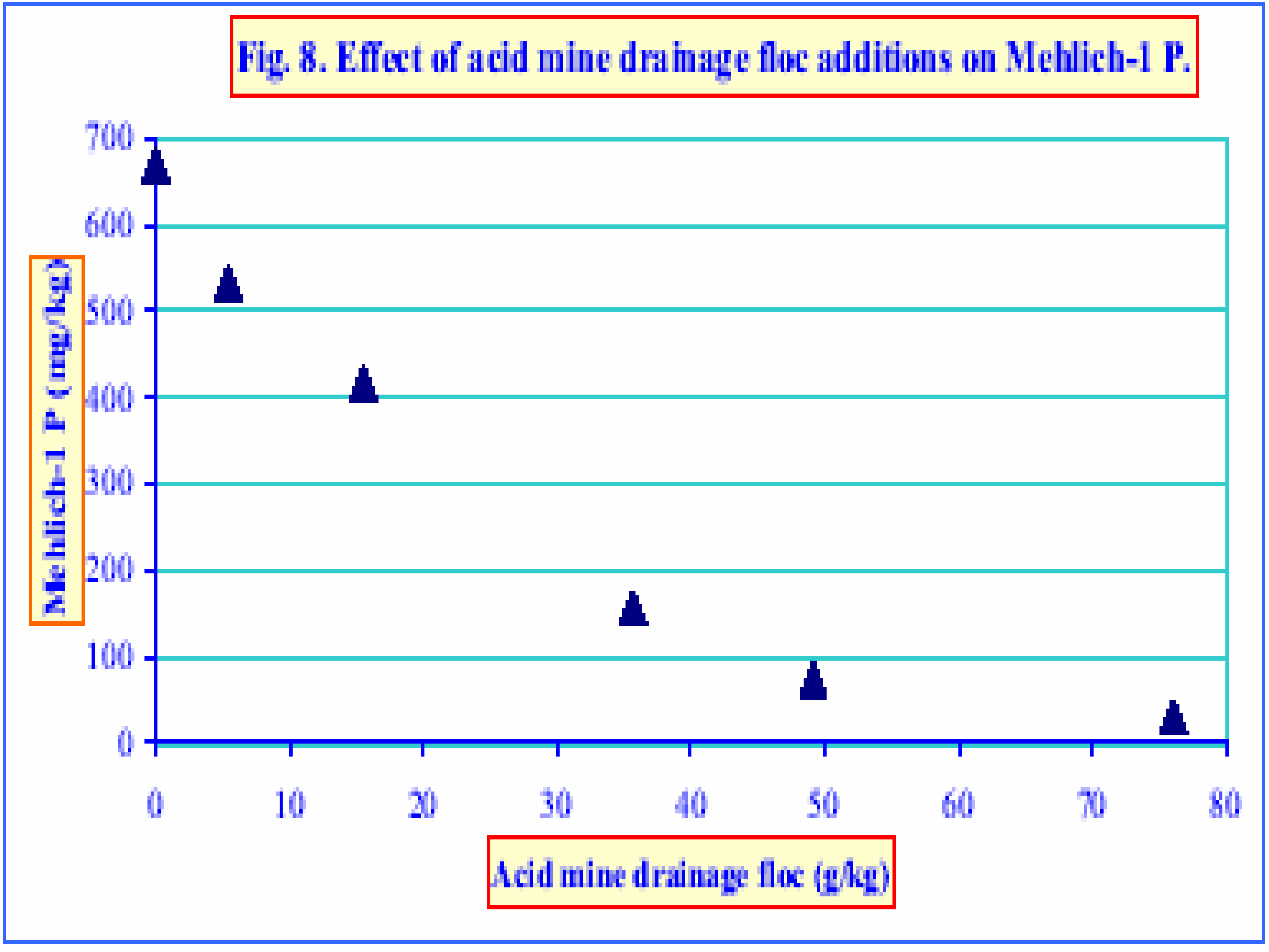
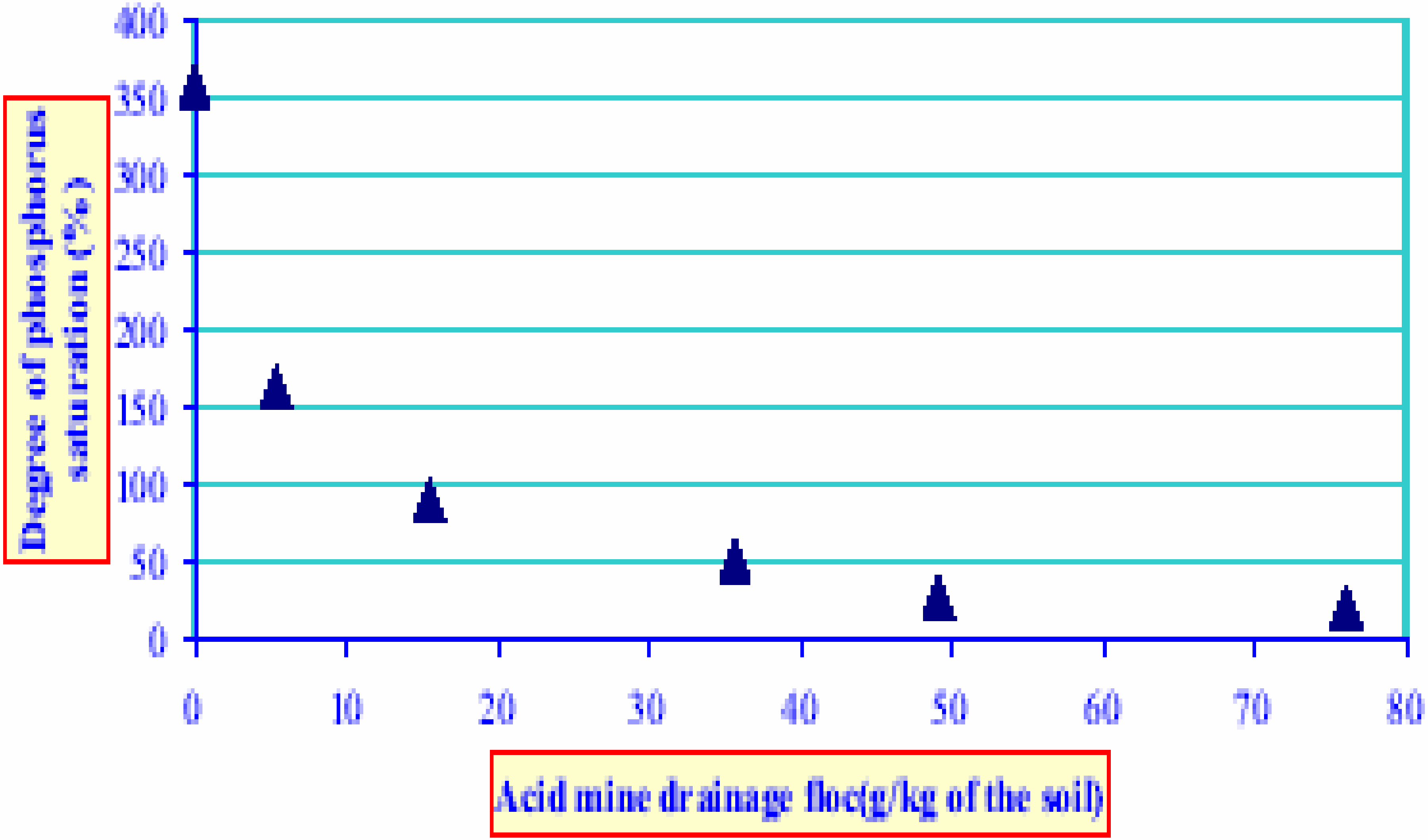


Fig. 8. Effect of acid mine drainage floc additions on Mehlich-1 P.
Mehlich-1 P (mg/kg)
700
600
500
400
300
200
100
0
0
10
20
30
40
50
60
70
80
Acid mine drainage floc (g/kg)

Fig. 10. Effect of acid mine drainage floc additions on degree of phosphorus saturation.



Border Strips

PHOSPHORUS

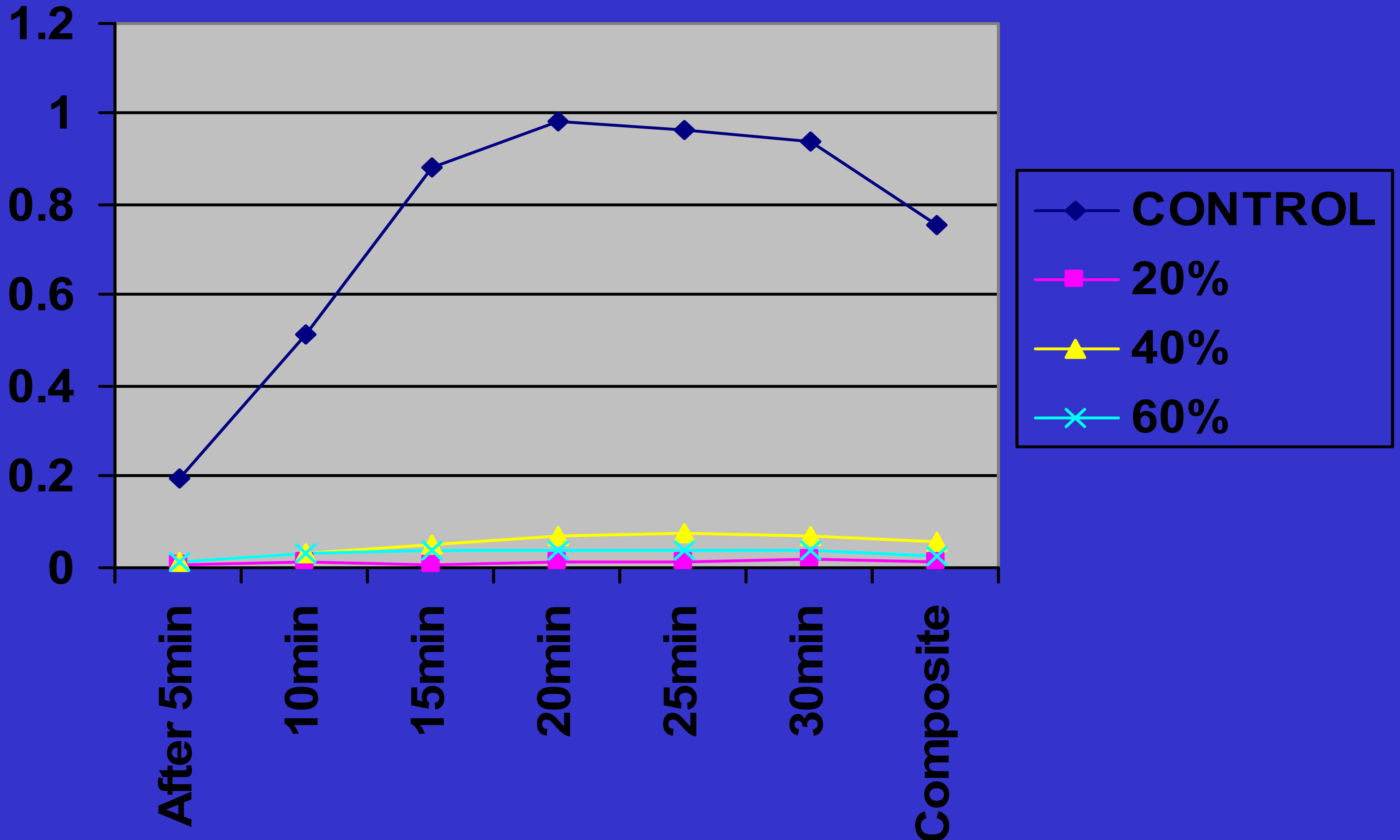

1.2
1
0.8
0.6
0.4
0.2
0
After 5min
10min
15min
20min
25min
30min
Composite
CONTROL
20%
40%
60%

Fig. 13. Effect of acid mine drainage floc buffer strips on dissolved P in runoff from site 1.

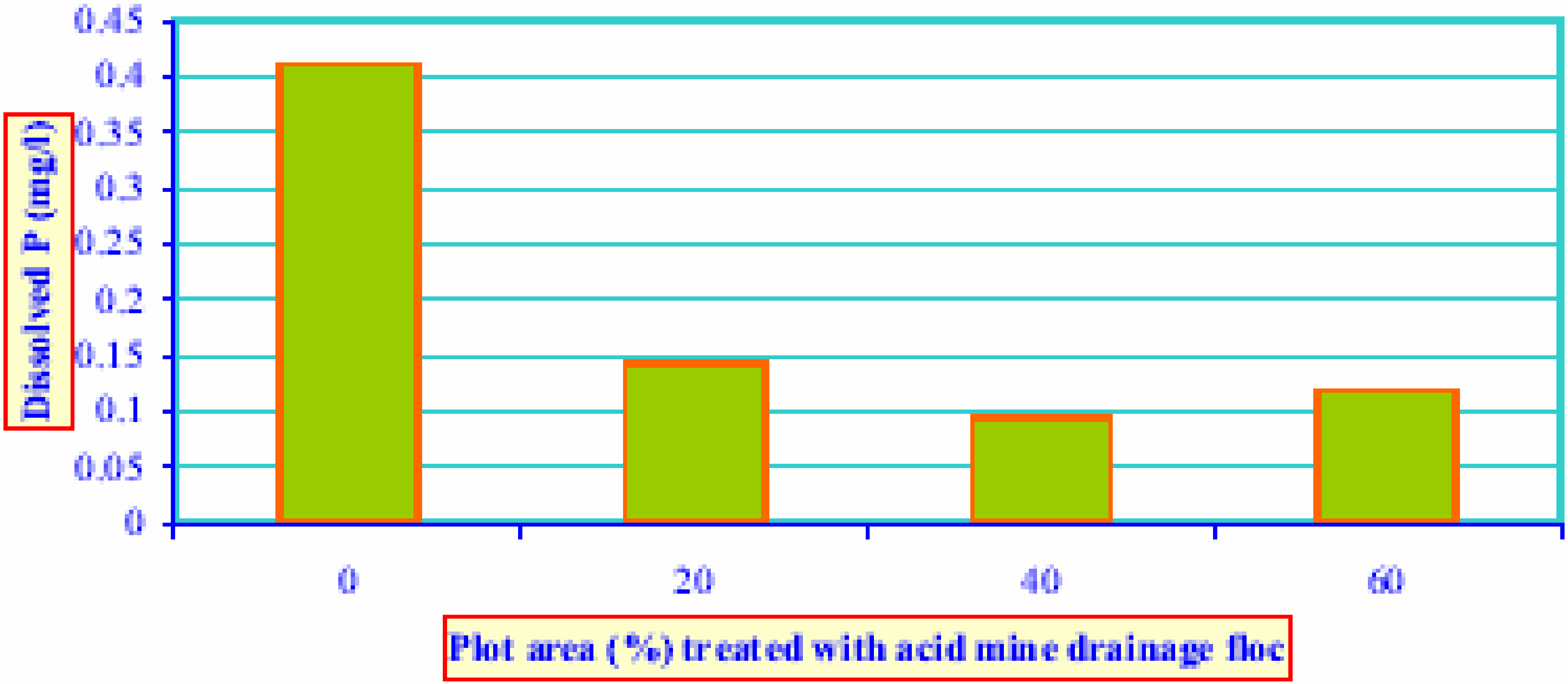
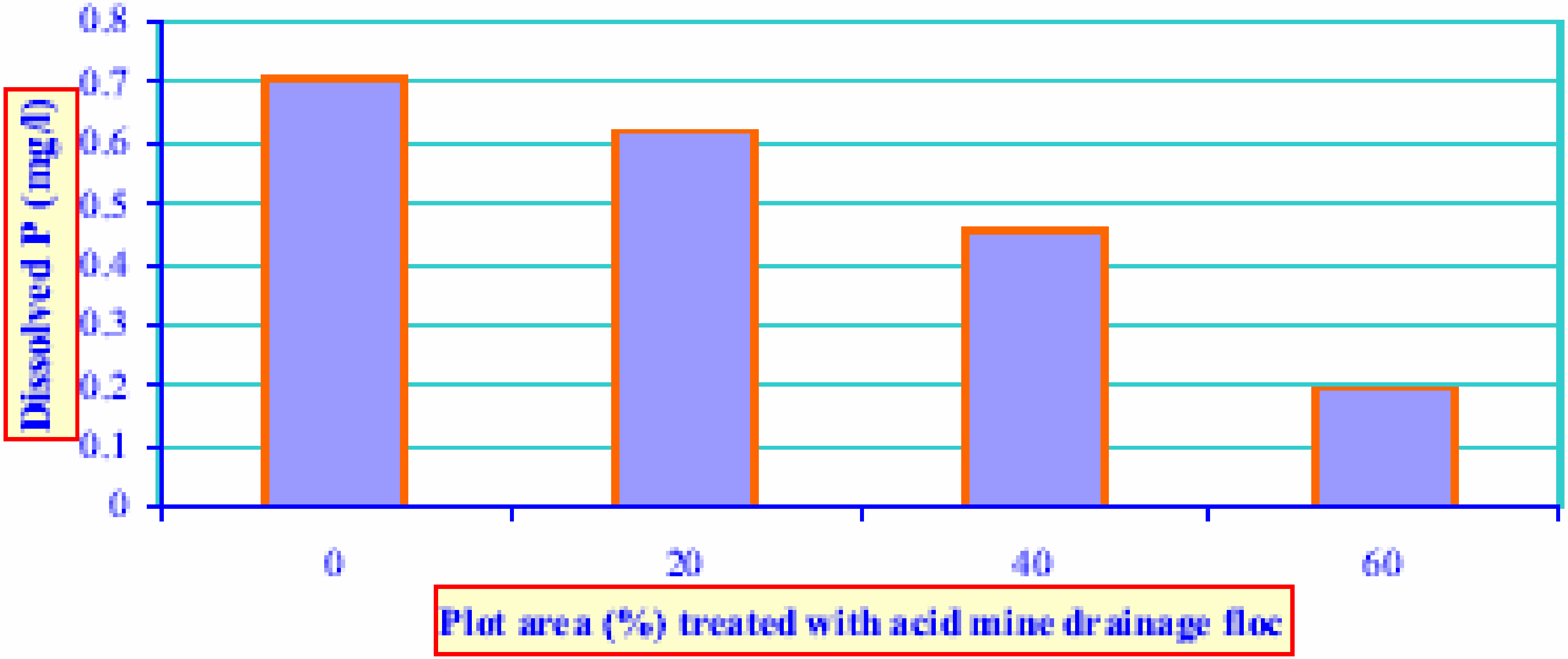


Fig. 14. Effect of acid mine drainage floc buffer strips on dissolved P in runoff at Site 2.



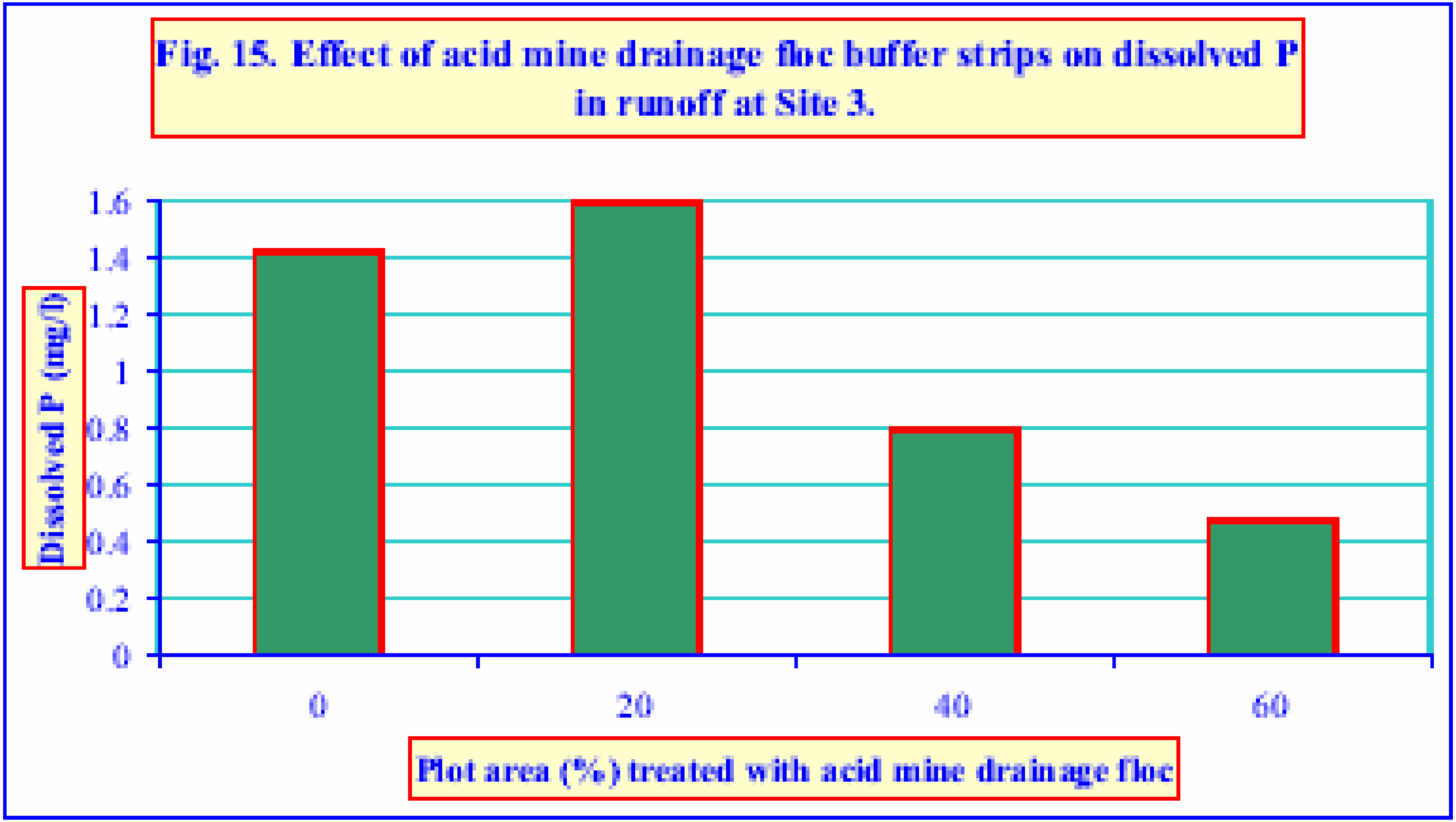
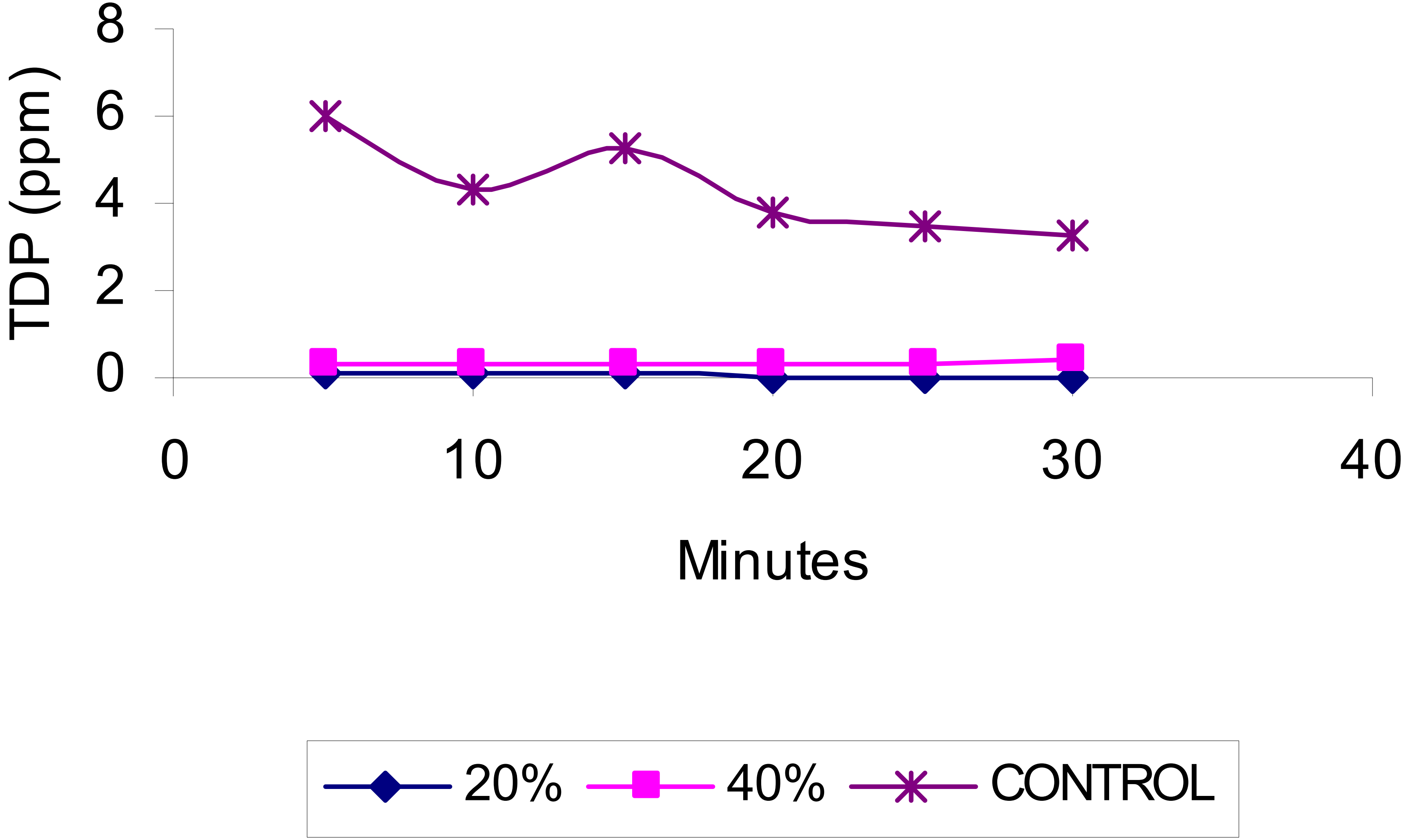


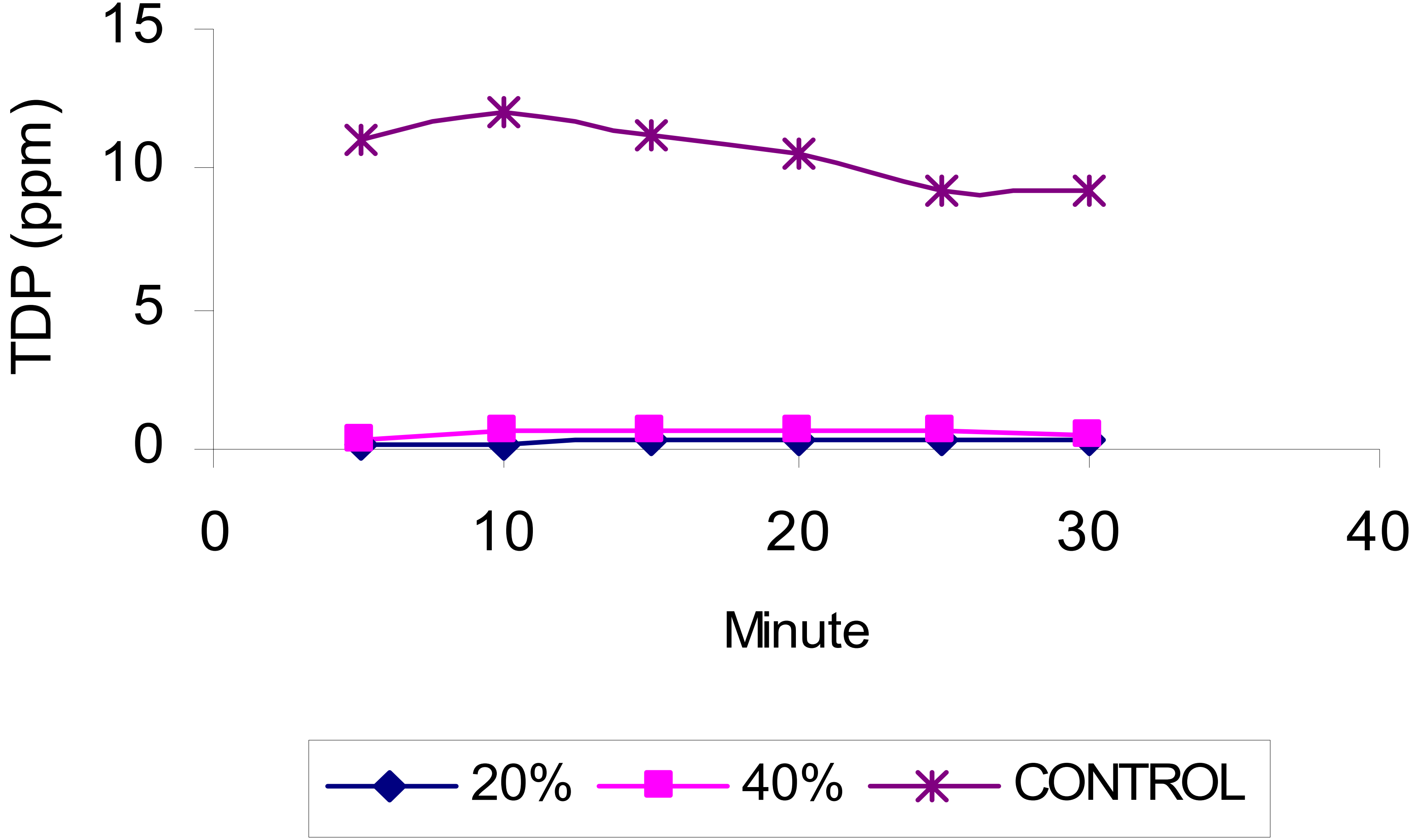
Fig. 15. Effect of acid mine drainage floc buffer strips on dissolved P in runoff at Site 3.
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Dissolved P (mg/l)
0
20
40
60
Plot area (%) treated with acid mine drainage floc

Manure Storage Areas

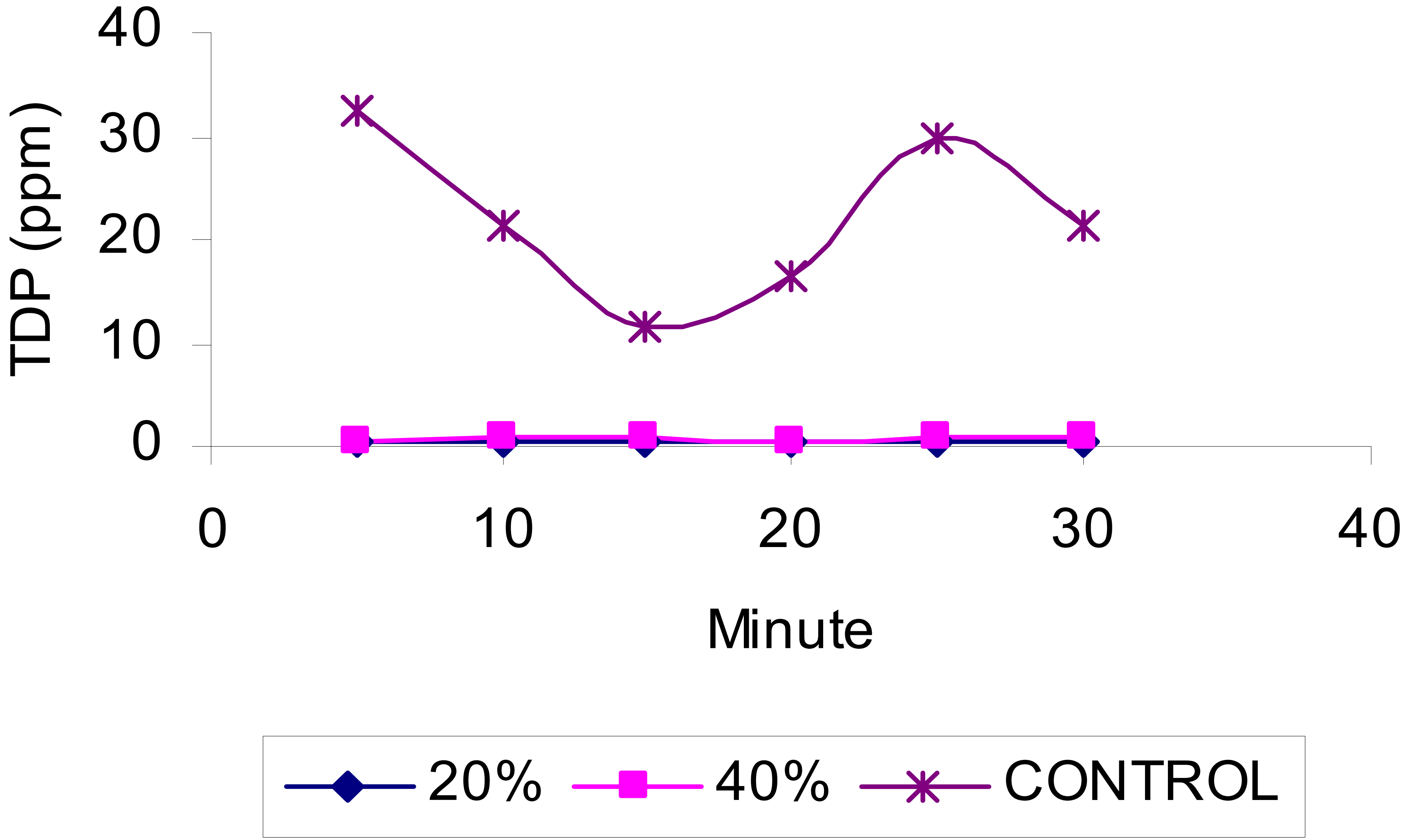
Total Dissolved Phosphorus In Runoff At 2% Slope



Total Dissolved Phosphorus In Runoff At 8% Slope



Total Dissolved Phosphorus In Runoff At 16% Slope



Conclusions

- Acid mine drainage floc has very high capacity to fix P
- High amounts of phytic acid phosphate is fixed by AMD flocs
- Border strips treated with AMD floc reduce dissolved P
- AMD floc reduces dissolved P from temporary manure storage areas

Acknowledgements

- WVSCA
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