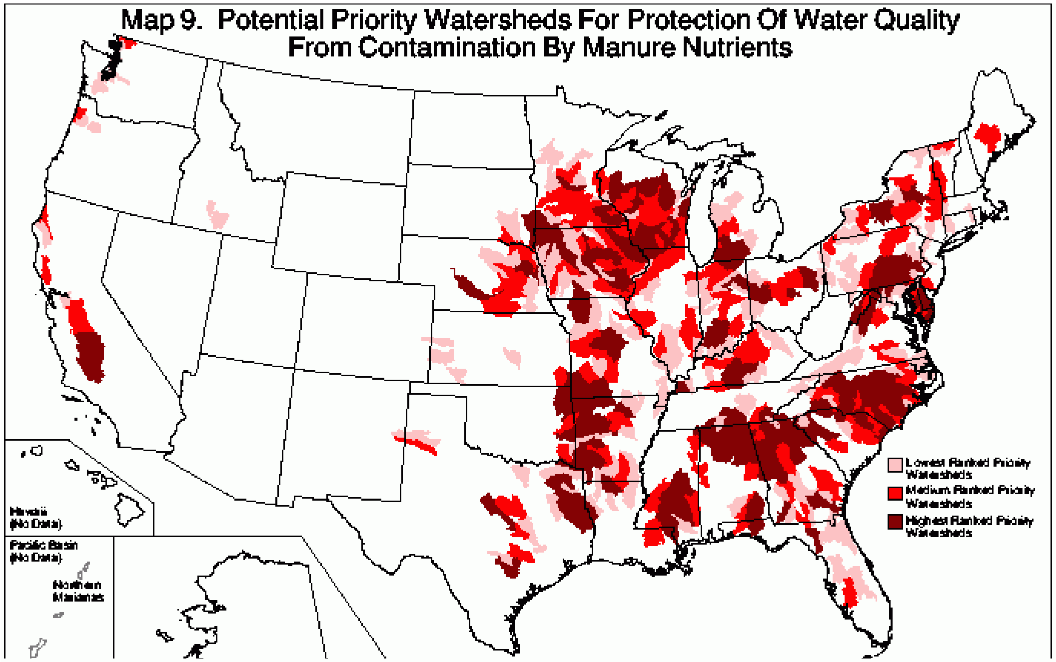
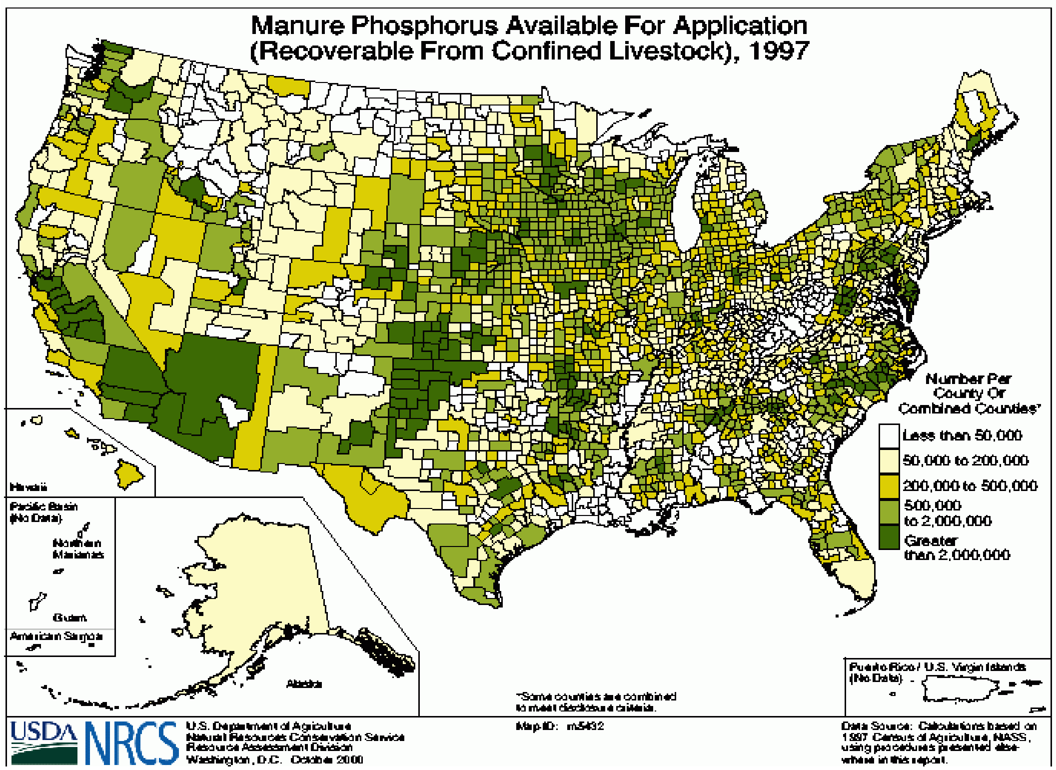
Beneficial Use of Municipal/Industrial Byproducts to Protect Surface Water Quality

E.A. Dayton & N.T. Basta
School of Environment and Natural Resources
The Ohio State University

Objective

Demonstrate ways municipal/industrial byproducts can be used beneficially as SORBENTS to mitigate non-point source agricultural pollution





Nutrient Contamination of Surface Water is of Increasing Concern

<u>Map 1</u>
Watersheds in Peril from P

<u>Map 2</u>
Areas of Manure P Availability

What is the Problem ?

- Phosphorus (P) is the nutrient most often implicated in the degradation of fresh surface water
- Historically, manure/biosolid recommendations were based on crop N requirements, resulting in a 2 to 3 fold excess P application
- P application in excess of crop requirements results in Potential Risk of P transport to surface/ground water

More Bad News

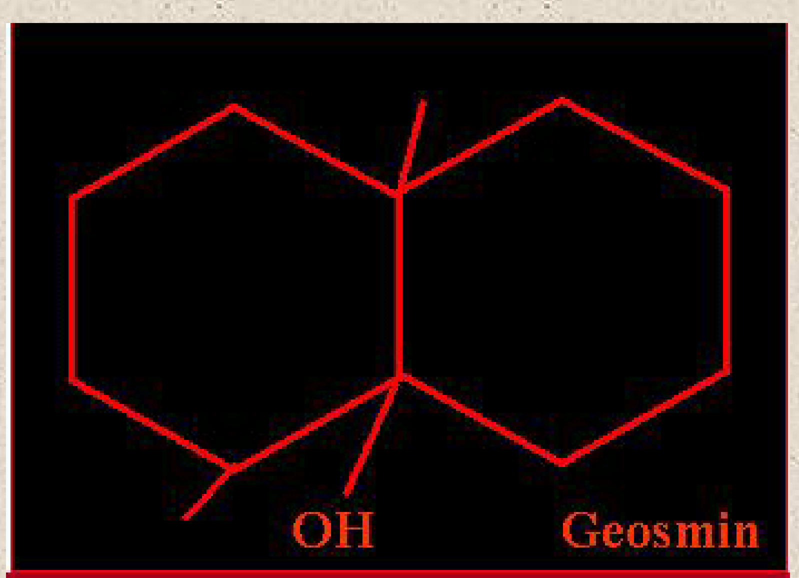
• There are 290,000 CAFOs (Concentrated Animal Feeding Operations) in the U.S.

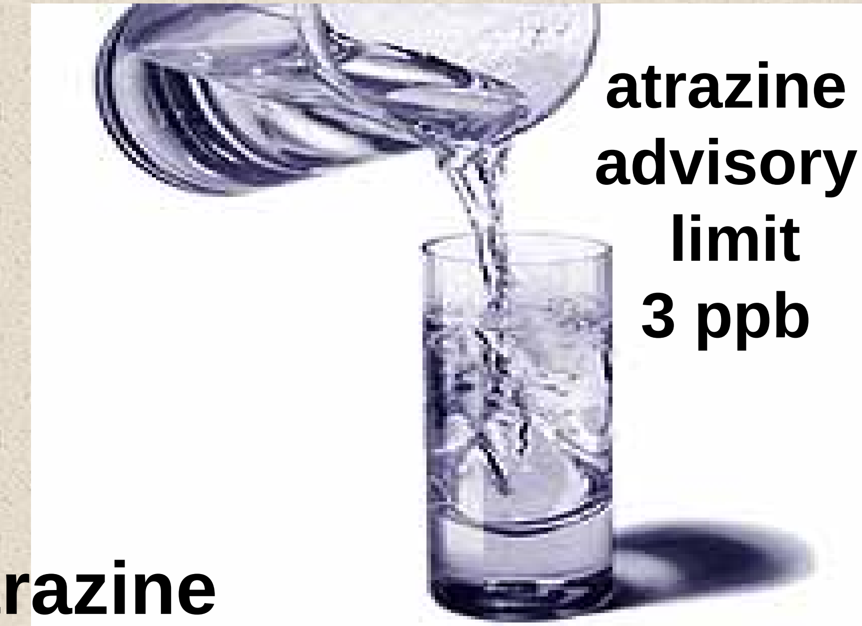
• 2.5 Million Tons of Manure P is generated annually in the U.S.

• USEPA Water Quality Inventory (2000) reported that > 33% of U.S. rivers, lakes, wetland & estuaries had degraded water qualitiy

Organic Contaminants and Surface Water

Organic Contaminants





Atrazine

Broadleaf Herbicide

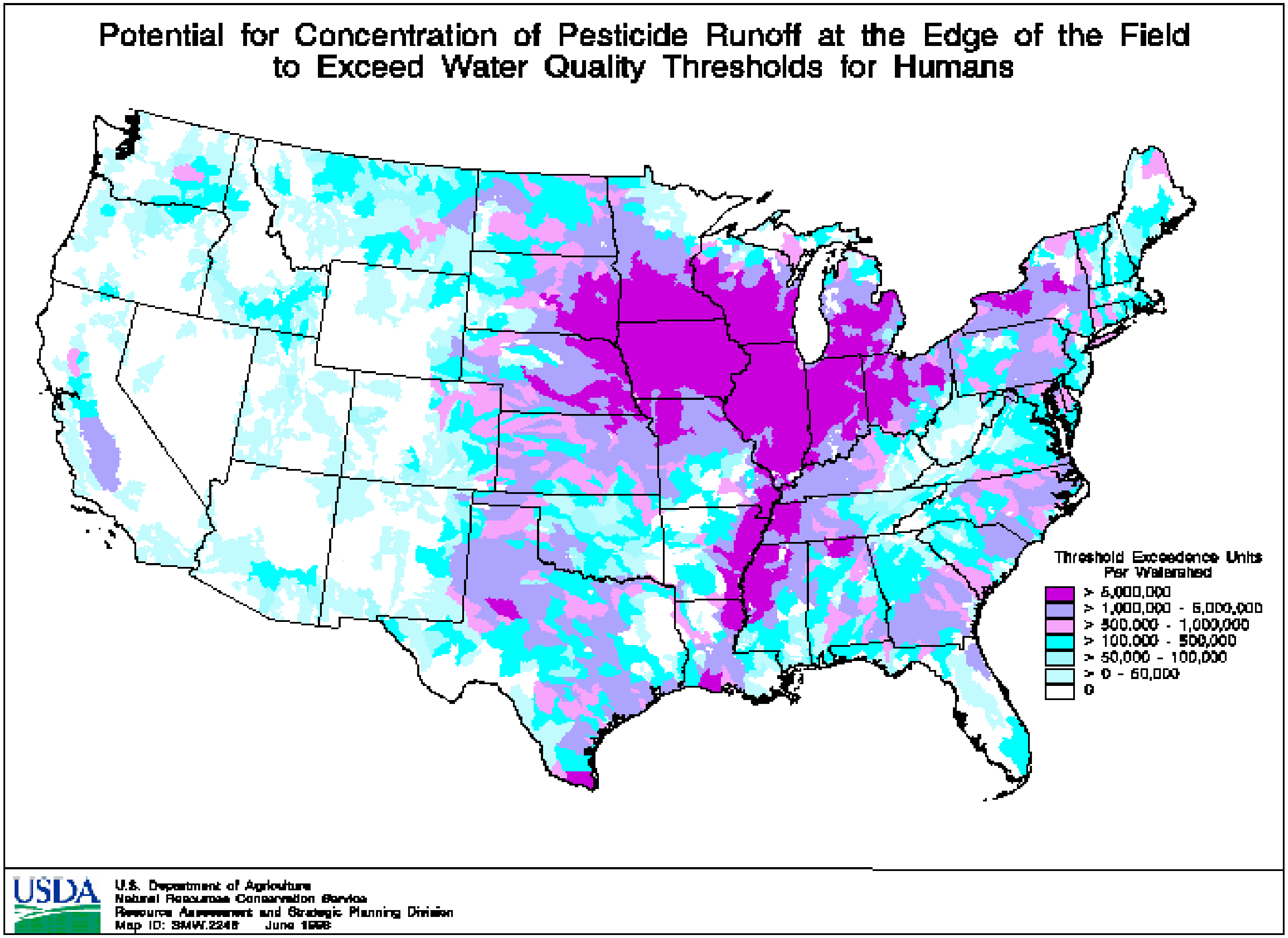
No.1 in US, 350 million lbs/yr

Geosmin -- chemical produced by algae (too much P nutrient)

very pungent -- water tastes bad at 3 parts-per-trillion
algal bloom levels > 500 to 1000 ppt

Geosmin removal -- PAC (powdered activated carbon)
EXPENSIVE

Risk of Non-Point Source Pesticide Runoff



Areas at Risk of Exceeding Water Quality Thresholds

Total U.S. Pesticide Use: 985 Million Pounds

EPA Draft ROE, 2003

Question

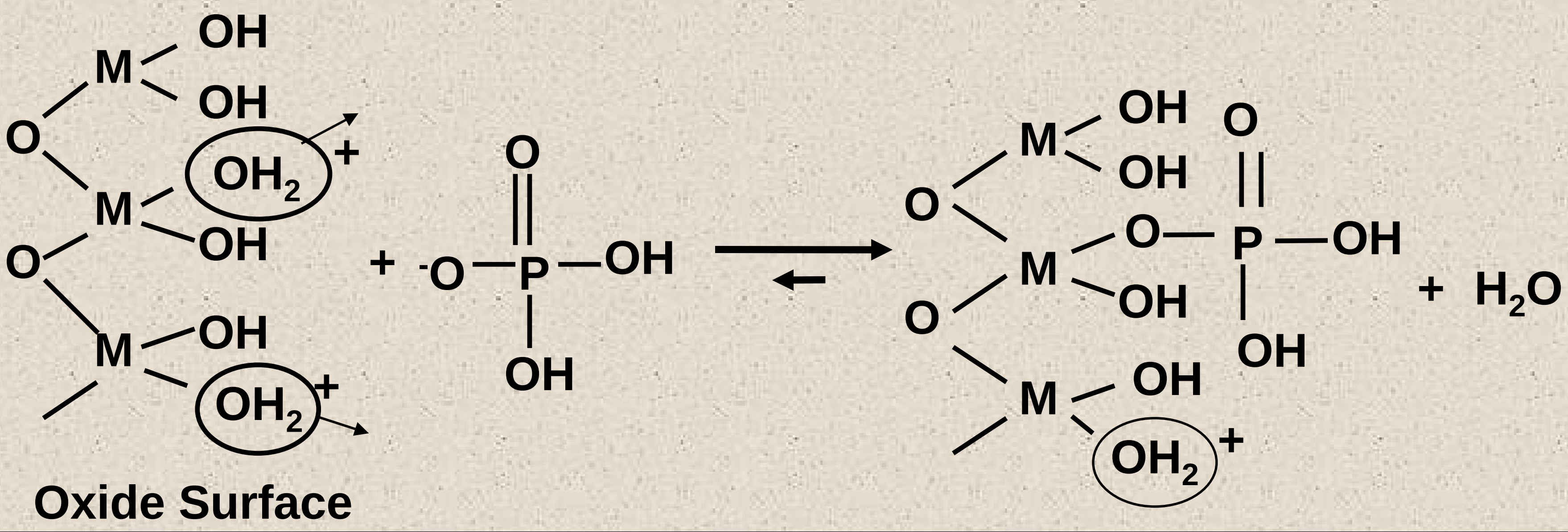
How does the problem of non-point source agricultural pollution relate to byproduct beneficial use and source water protection?

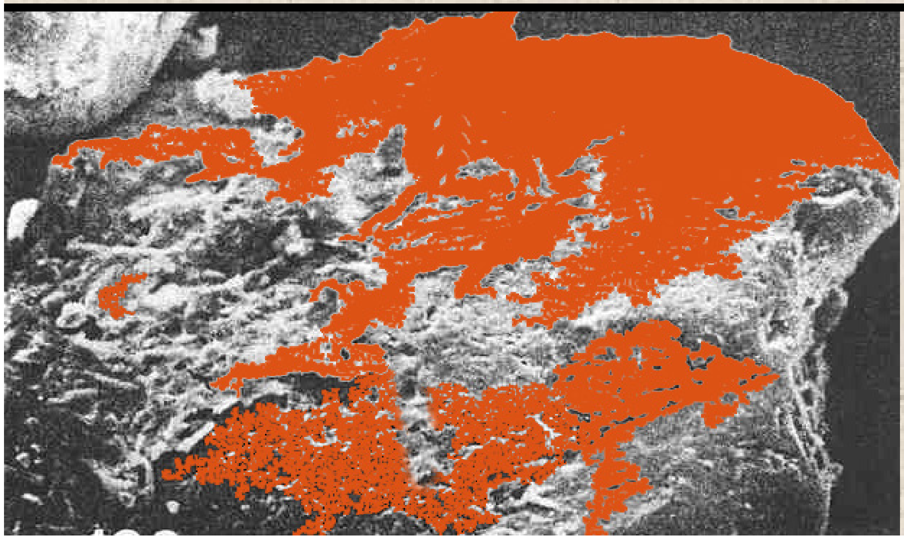
Answer

Byproducts can be beneficially used as SORBENTS to intercept and bind non-point source agricultural pollution and prevent the degradation of surface water

Byproduct Reactive Surfaces

Hydrous metal (M) oxides of Al, Fe or Mn naturally occurring soil minerals





Byproducts rich in organic C bind organic contaminants

Drinking Water Treatment Residuals (WTR)

Rich source of hydrous metal oxide surfaces

Contain

- **Sediment**
- **Organic material**
- **Coagulant reaction products (Al or Fe oxides)**

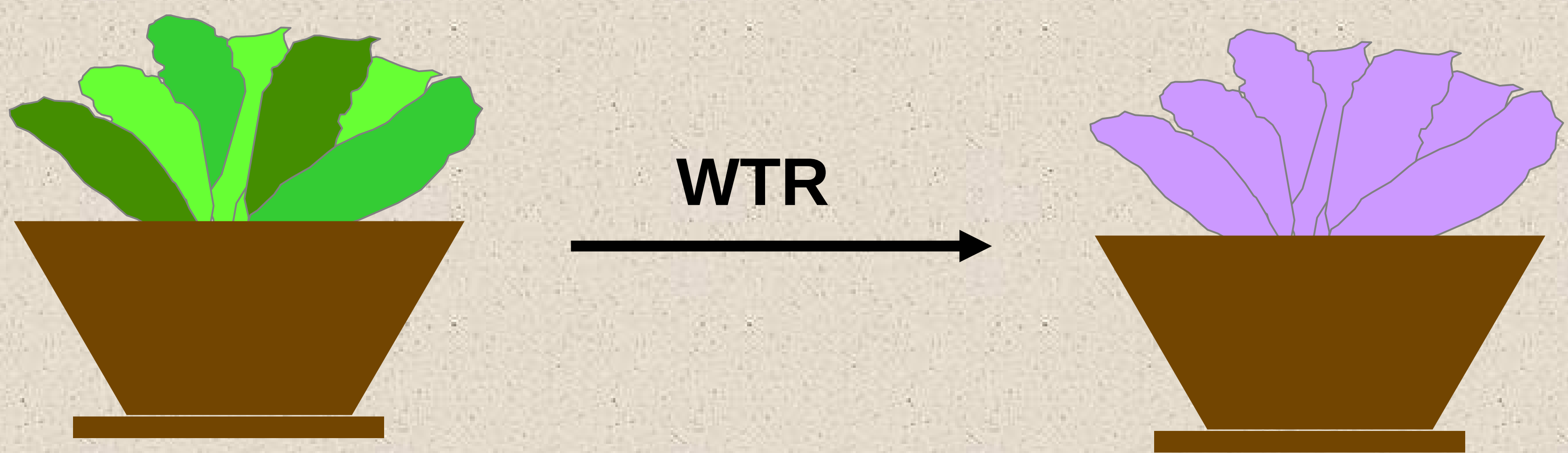
Disposal

- **Landfill**
- **Store in on-site lagoons**
- **Discharge to sanitary sewer system**

OSU Previous WTR Research

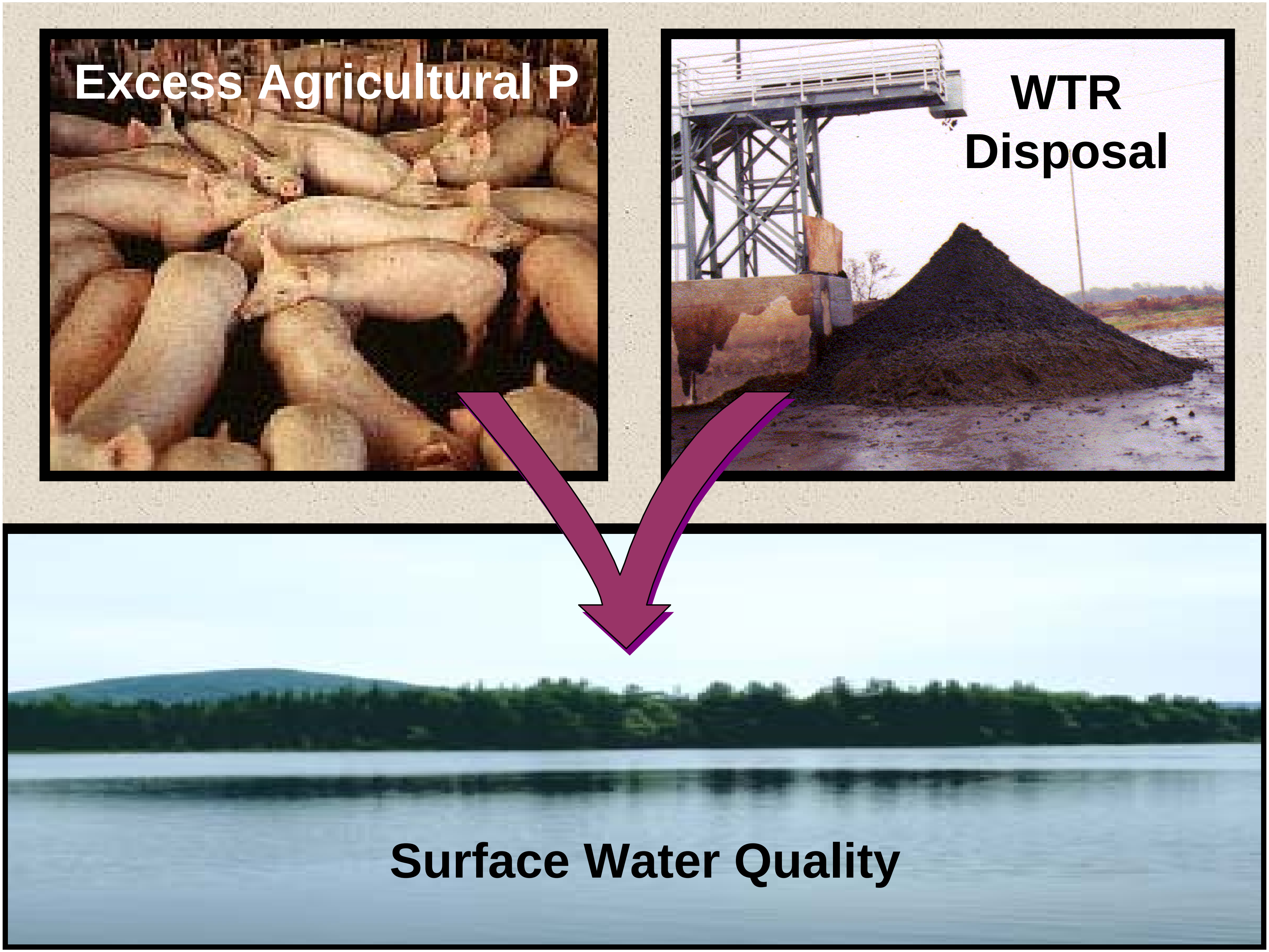
Characterization	Results
E.A. Dayton & N.T. Basta. 2004. J Environ Qual. 34:1112-1118	Evaluated and modified soil tests for use with WTR
E.A. Dayton et al. 2001. Water Env. Res. 73:52-57	Characterized WTR use as soil substitute or as P sorbents
Growth Studies	
Gallimore et al., 1999	Poor growth of low P tolerant native grasses
E.A. Dayton et al. 2001. Water Env. Res. 73:52-57	Poor growth of tomato
N.T. Basta et al. 2000. J. Environ. Qual. 29:2007-2012	Poor growth of bermudagrass despite additions of P fertilizer
Land Application	
E. A. Dayton & N.T. Basta. 2005. J. Environ. Qual. 34:2112-2117	P reductions due to WTR can reduce P risk scores
E.A. Dayton et al. 2003. J. AWWA 95:151-158	Runoff P reduction related to WTR Pmax & Alox
Gallimore et al. 1999 J. Environ. Qual. 28:1474-1478.	Decreased runoff P from poultry litter-treated land
Basta & Storm, 1997	Decreased runoff P from poultry litter-treated land
Peters & Basta, 1996. J. Environ. Qual. 25:1236-1241.	Decreased soil test P and soluble P

WTR P Sorption and P Deficiency



P deficiency

Gallimore Basta and Storm, 1999
Dayton and Basta, 2001
Zupancic, Basta and Dayton, 2000

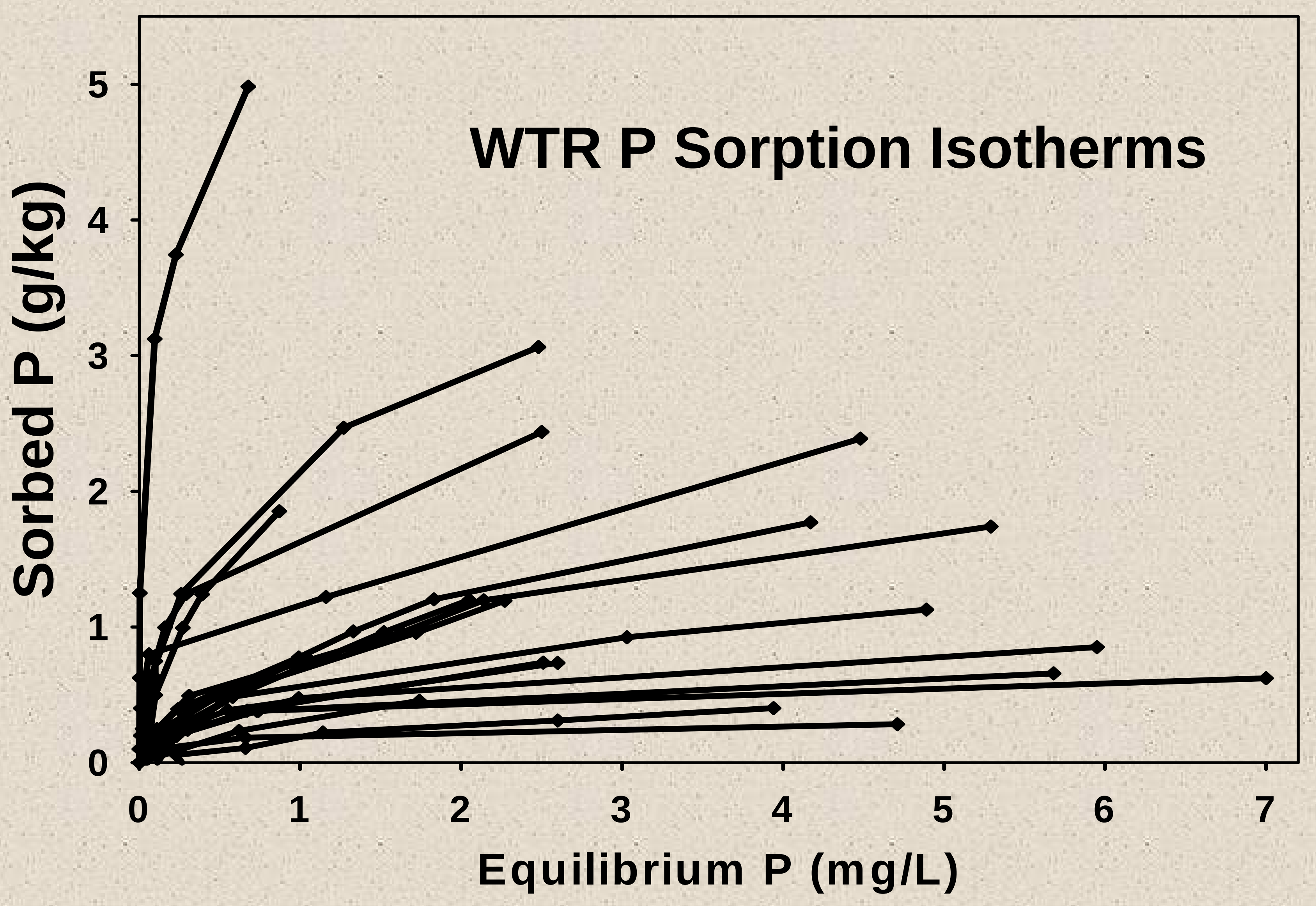

Excess Agricultural P
WTR
Disposal
Surface Water Quality

Current Approach

1. Evaluate and adapt standard soil methods to accurately determine Langmuir P sorption maximum (P_{max}) and amorphous Al/Fe (Al_{ox} & Fe_{ox}) in WTR

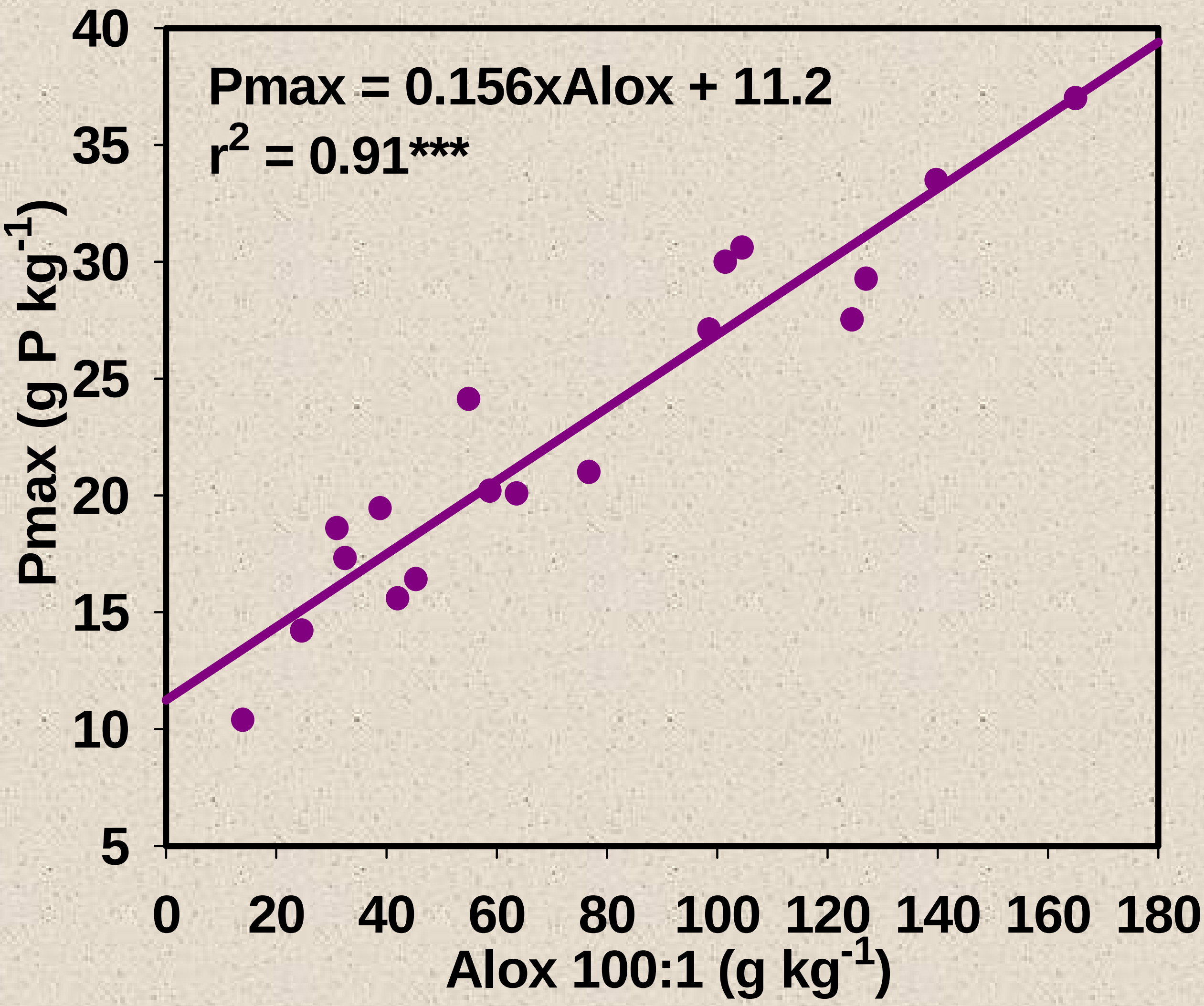
2. Test land application methods to use WTR in a P Risk context
   - Surface application (runoff)
   - Co-blending with organic waste material (manure, biosolids)
   - Incorporation into soil

Adapted Standard Soil Methods



WTR P Sorption Maxima (P_{max})

Highly correlated with hydrous metal oxide (Al_{ox})



Dayton and Basta, 2004

Conclusions Part 1

Accurate measure of P_{max} is necessary to calibrate WTR land application to achieve target P reductions

A strong empirical relationship between P_{max} vs. Al_{ox} allows for calculation of P_{max} without the onus of generating P sorption isotherms

Evaluate WTR Land Application Options

Field Crops — Incorporate Into Soil → **P Solubility**
- Soluble P
- Soil Test P

Pasture — Surface Apply Manured Land → **Runoff P**
- Soluble P

Co-application — Blend With Waste → **P Solubility**
- Biosolids
- Manure

Recent Project

Interregional Study Funded by
American Water Works Research Foundation

Ohio State University/McGuire Environmental
Participating utilities from:
Tulsa OK
Denver Metro CO
Pennsylvania American PA

Objective:

Recommend procedures for utilizing WTR as a best management practice (BMP) to reduce P Risk

Materials

Six Alum-based WTR

	Amorphous Oxide*			
WTR	Al_{ox}	Fe_{ox}	P_{max}§	pH
	--- mol kg^{-1} ---		g kg^{-1}	
A	3.55	0.034	27.1	7.04
B	1.08	0.063	18.6	7.24
C	3.21	0.004	23.7	7.51
D	4.80	0.330	32.6	6.93
E	4.22	0.220	29.3	6.98
F	3.98	0.237	31.7	6.75

*Acid ammonium oxalate extractable Al and Fe.

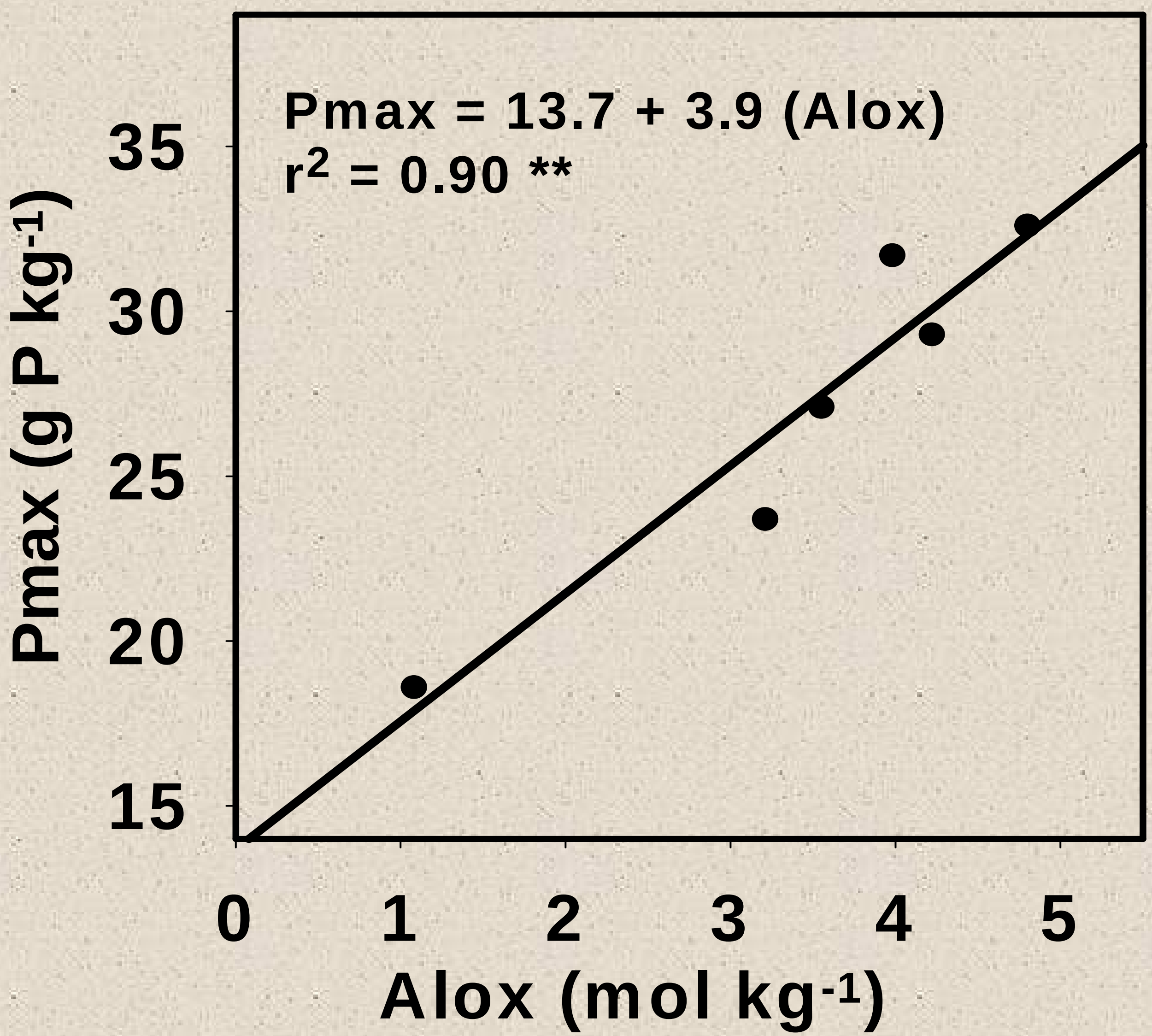
§Langmuir phosphorus (P) sorption maximum.

Other Materials Used in the Study

	Metal Oxide		Extractable P*	
Material	Al	Fe	$CaCl_2$	MIII
	-- mol kg^{-1} --		-- mg kg^{-1} --	
Tonti Soil	0.041	0.018	13.6	315
Poultry Litter	0.023	0.045	2,054	10,160
Biosolid	0.344	0.186	62.5	1,676

* 0.01*M* $CaCl_2$ and Mehlich III

Relationship Pmax vs Amorphous Al



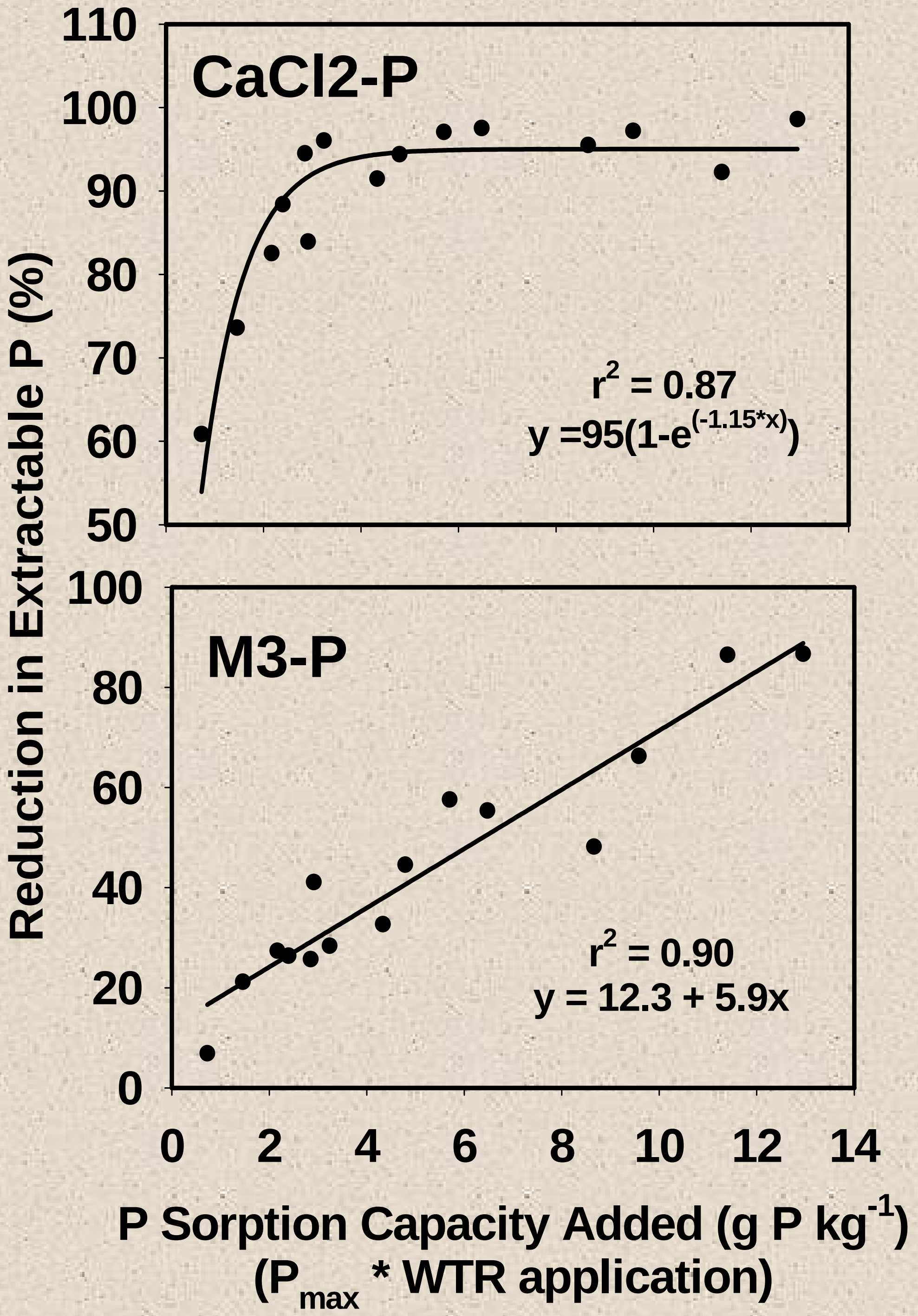
Soil Incorporation Study

Tonti silt loam soil containing

13.6 mg P kg^{-1} (0.01M) $CaCl_2$ extractable P
315 mg P kg^{-1} MIII extractable P

WTR Blended at:
0, 1, 2.5, 5 and 10%

Incubate for 4 wks
30°C
kept moist



Results of Soil Incorporation Study

% Reductions in extractable P after incubation of Tonti soil with WTR

Runoff Study

- Using rainfall simulation
- Plots filled with Tonti soil
- Poultry litter applied at 4 ton $acre^{-1}$
- WTR applied as a Buffer Strip at:
  0, 5, 10 and 20 Mg ha^{-1}
- Runoff water collected for 30 min.

Simulated Rainfall Setup

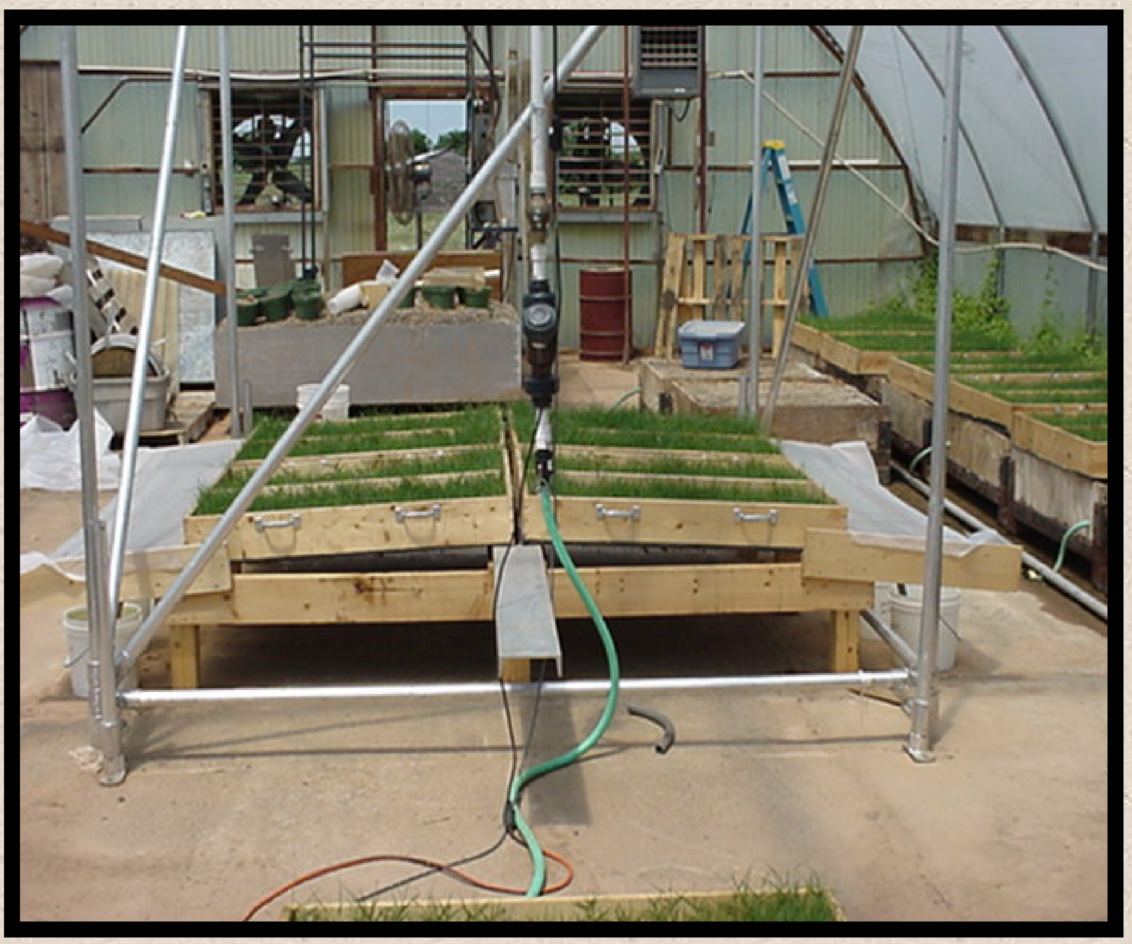
Runoff Study

Simulated rain
7.5 cm h^{-1}

5% Slope

Runoff collected for 30 min

Filter (0.45 µm)

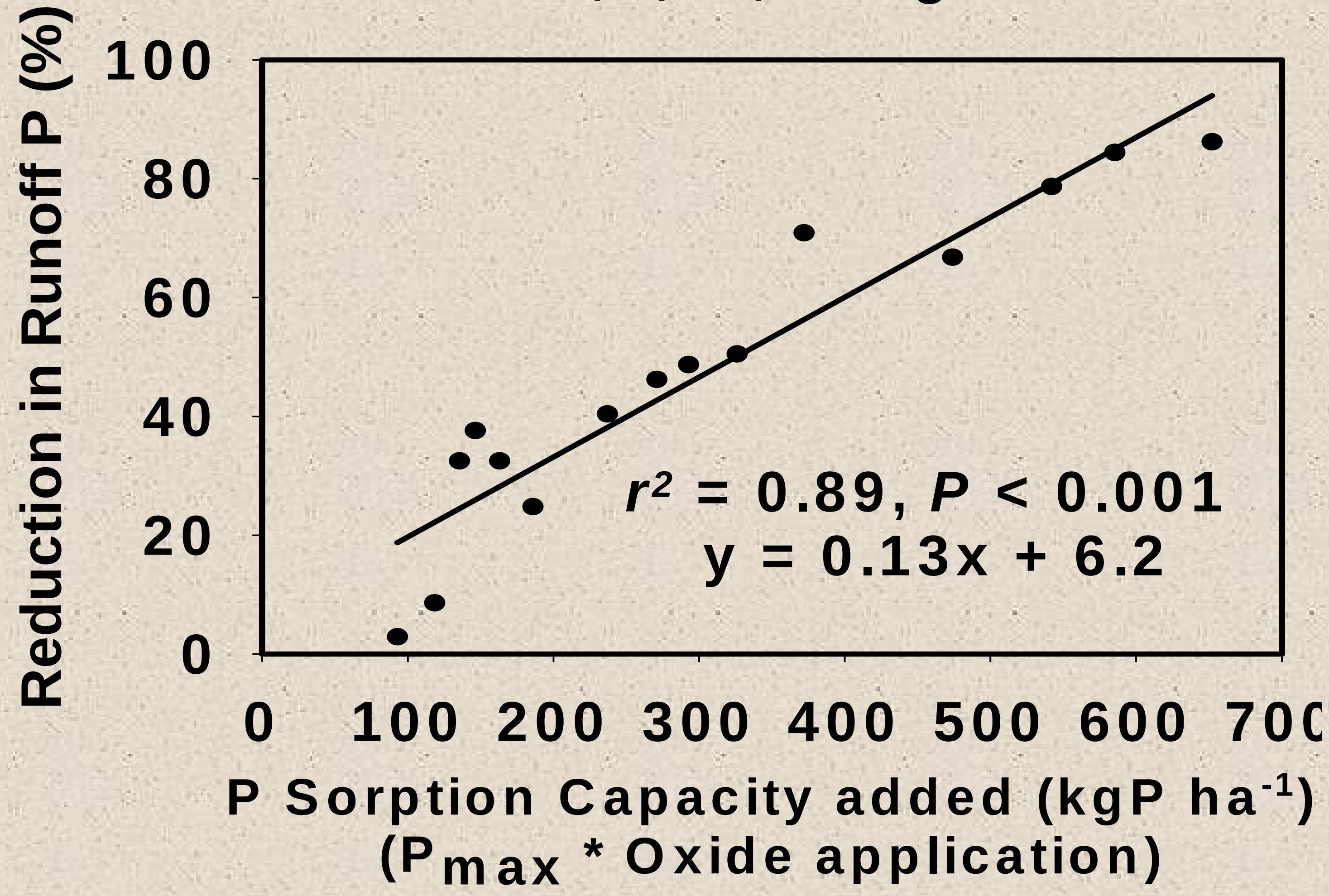


Dayton, Basta & Jacober, 2003

Results of Runoff Study

Control = 31 mg P /L

Oxide Additions of 0, 5, 10, 20 Mg/ha in a filter strip



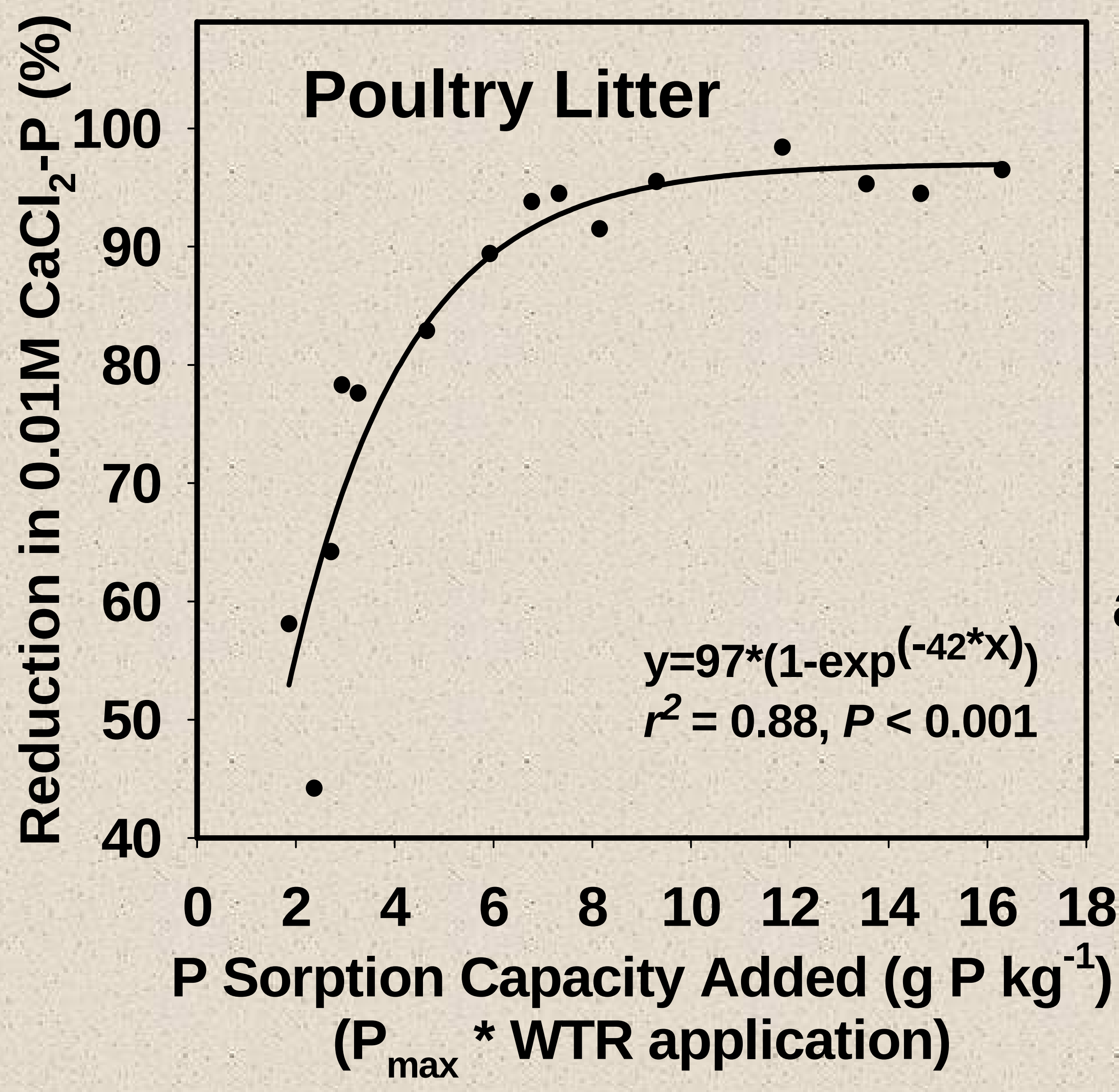
Dayton & Basta, 2005, JEQ 34:2112-2117

Co-blending with Organic Byproducts Study

Material	Extractable P $CaCl_2$
	mg kg^{-1}
Poultry Litter	2054
Biosolids	62.5

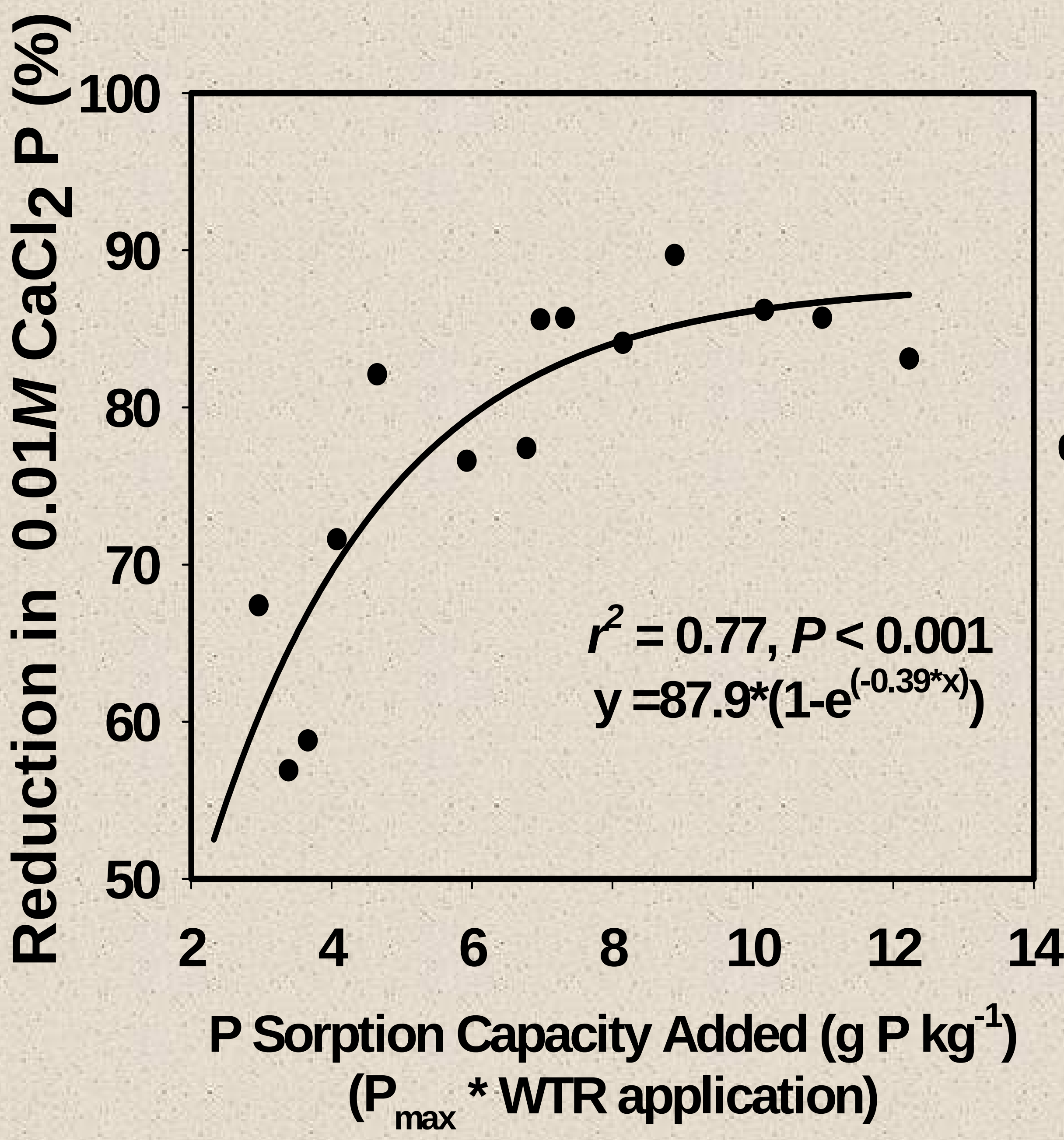
WTR Blended with:
Poultry litter at: 0, 10, 25, 50 and 75%
Biosolids at: 0, 5, 12.5, 25, and 37.5%

Incubate for 12 wks at 25°C



Results of Soil Co-blending Study

% Reductions in extractable P after incubation of poultry litter with WTR



Results of Soil Co-blending Study

% Reductions in extractable P after incubation of biosolids litter with WTR

WTR Is An Effective P Sorbent !

The beneficial use of WTR will provide:

Economic benefit to utilities

Economic and environmental benefits to communities

Non-Point Source Pesticide Pollution

Spent foundry sands (SFS) may be a rich source of organic C surfaces

Approach:

Identify the ability of SFS and SFS blends

to retain pesticides

1. **Characterization of sorbent properties of SFS**

2. **Pesticide (Atrazine) sorption study**

Current Project

Part of
USDA-ARS Foundry Sand Research Initiative (2002)

Ohio State University's Research Component

SFS Characterization
- **43 SFS from 12 states**

Beneficial Use of Foundry Sand
- **Component in soil blend**
- **Pesticide sorbent**

USDA ars United States Department Of Agriculture Agricultural Research Service

THE OHIO STATE UNIVERSITY

Characterization of 43 SFS Materials

Amorphous Fe, Al: P sorbent
- low to typical soil level

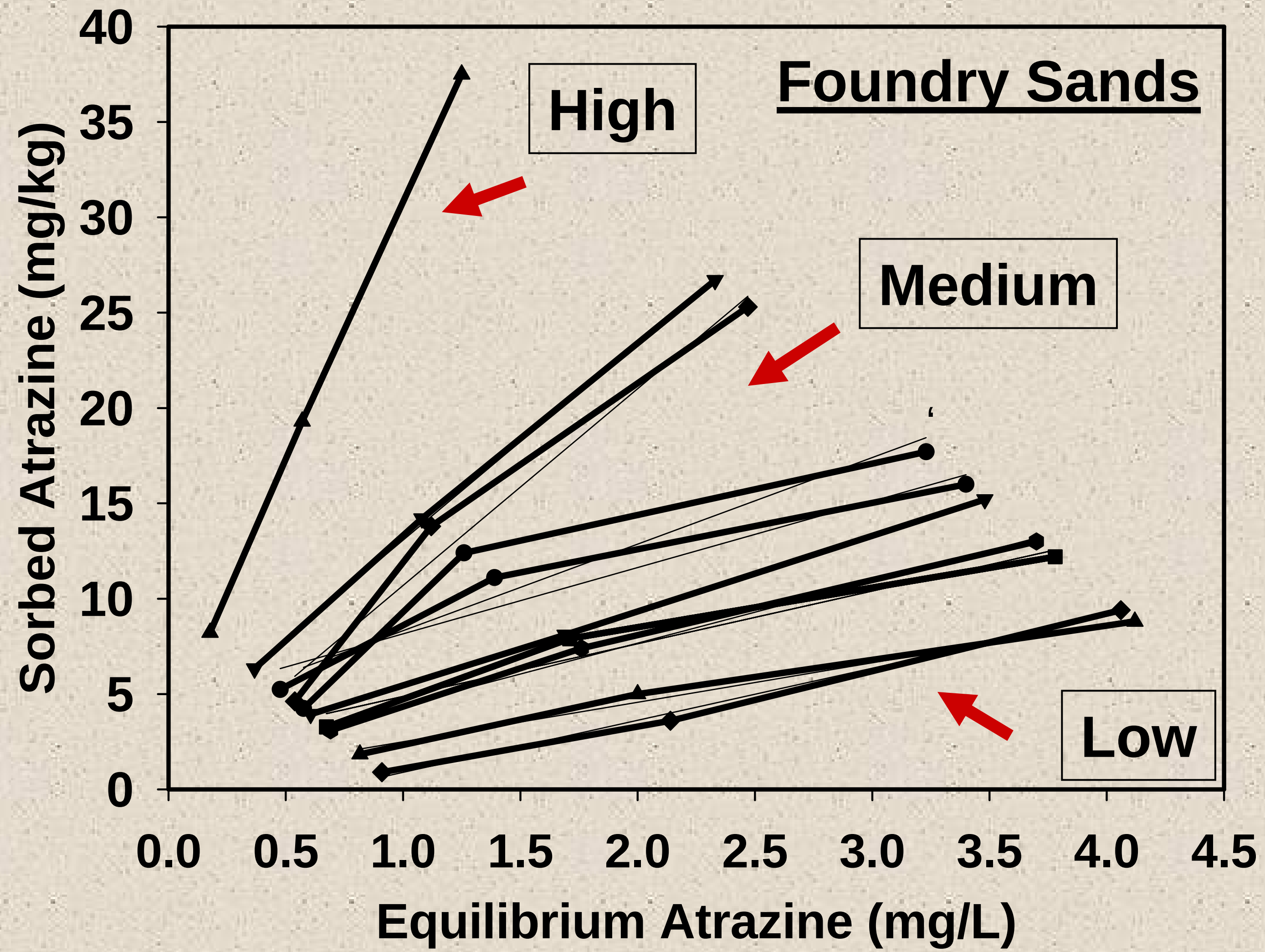
Organic C: pesticide sorbent
- moderate to high

pH and EC: growth media
- high pH, EC OK

	Alox	Feox	OC	pH	EC
	g/kg		%		dS/m
Minimum	0.053	0.054	0.32	5.44	0.043
Maximum	2.43	32.1	5.8	10.76	2.53
Mean	0.42	3.64	1.9	8.67	1.33
Soil Typical Level	< 20		0.06–6.0	5.0–8.3	<4.00

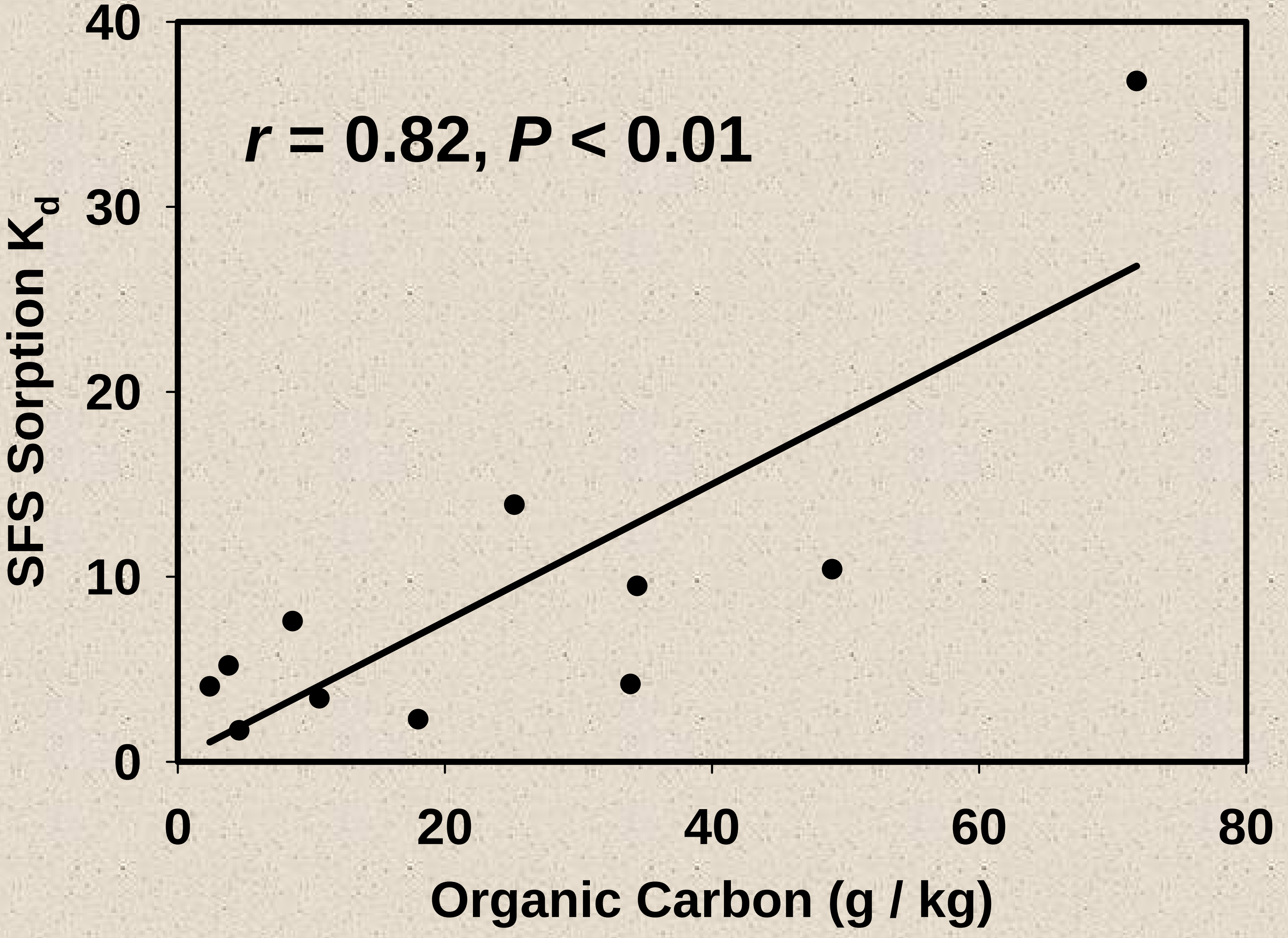
Byproducts as Pesticide Sorbents

Byproducts RICH in Reactive Organic C



Results from Atrazine Sorption Study

Atrazine sorption related to SFS OC



Conclusions

Industrial/Municipal byproducts can be effective SORBENTS of non-point source agricultural pollution

However in order to be used, sorbents must become OFFICIALLY recognized as a BMP

Further, permitting authorities (EPA) must understand the benefits and be willing to write permits

Questions ??

Elizabeth (Libby) Dayton
dayton.15@osu.edu