

agronomy news

Managing Agricultural Phosphorus To Protect Water Quality

Phosphorus in runoff impairs surface water quality.

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Concern about agricultural nutrients and water quality is nothing new in Colorado, but in the past our attention was focused mainly on impacts from nitrogen.

Phosphorus (P) is now receiving much attention nationwide as an important surface water pollutant. Surface water that receives phosphorus due to soil erosion, runoff from feedlots, or irrigation suffers from the process of accelerated eutrophication. Eutrophication is the natural aging of lakes or streams brought on by nutrient enrichment. Eutrophication has



been identified as the main cause of impaired surface water quality across the country. This decline in water quality restricts fishing, recreation, and drinking uses

due to the increased growth of undesirable algae and aquatic weeds and to oxygen shortages caused by their death and decomposition.

Agriculture is not the only source of P in the aquatic environment. For example, the USGS estimates

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Impact

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that almost 2 million pounds of P are added to the South Platte each year from municipal waste discharges directly into the river.

They report that manure and fertilizers applied to cropland and lawns make up the majority of the P load in the basin.

One of the difficulties in achieving better management of P fertilizer is that small, economically insignificant amounts of P are enough to cause water quality impairment. Lake water concentrations of P above 0.02 ppm generally acceler-

ate eutrophication. These values are an order of magnitude lower than P concentrations in soil solution critical for plant growth (0.2 to 0.3 ppm), emphasizing the disparity between critical lake and soil P concentrations.

Continual long-term application of fertilizer or manure at levels exceeding crop needs will increase soil P levels. In many areas with confined animal production, manures are normally applied at rates designed to meet crop N requirements but to avoid ground water quality problems created by leaching of excess N. Nitrogen-based management has been advocated by

Extension and other crop advisers for many years. The result is a buildup of soil P to excessive levels over time. In many cases we now will need to recommend P based management, significantly increasing the number of acres needed to accommodate all of the manure produced. Livestock and crop producers are going to need help in understanding why they should consider implementing such a radical shift in their nutrient management approach. This newsletter attempts to provide some information to consider in managing agricultural P to protect water quality.

Reagan Waskom

Table 1. Comparison of manure application rates based upon corn N versus corn P needs.

Nutrient used to determine manure rate	Available from Manure (1 st year)	Crop Nutrient Requirement**	Manure Rate	Supplemental Fertilizer Required
	---lbs / ton---	--- lbs / acre---	-- tons / acre-	--- lbs / acre---
Nitrogen	10	250	25 (N-based)	0
Phosphorus (P ₂ O ₅)	20	122	6 (P-based)	180

*Example based upon actual soil and manure analysis, 35-ton silage corn yield goal for a Weld County field.

**Nitrogen requirement after residual soil nitrate and organic matter credits. Phosphorus requirement based upon crop removal and 80% firstyear availability.

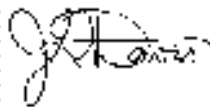
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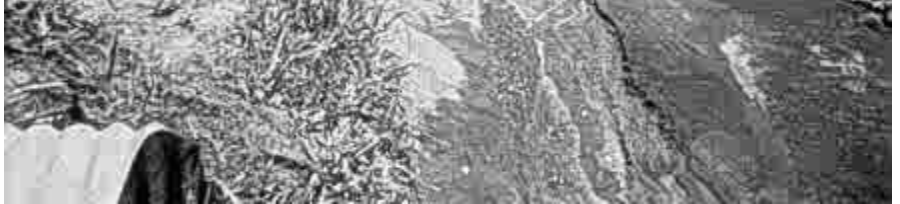
Phosphorus In Colorado Streams And Reservoirs

Irrigation waters contain more phosphorus than you think.

Phosphorus is the nutrient that often limits primary productivity in aquatic ecosystems, while nitrogen limits terrestrial productivity. Phosphorus (P) sources exist in both inorganic and organic forms. Inorganic forms (e.g., phosphates) originate from apatite minerals. Plant and organic biomass residues are the primary source of organic P. Other important sources of P include commercial fertilizers and manure, land application of biosolids, wastewater treatment plants (WWTP), livestock grazing, non-agricultural fertilization, and septic systems.

The easiest and most common measurements of phosphorus are orthophosphate-phosphorus ($\text{PO}_4\text{-P}$) and total phosphorus (TP). Water samples are usually filtered through a 0.45 micron pore size filter to separate dissolved from total P.

The filtered solution includes the orthophosphate-phosphorus ($\text{PO}_4\text{-P}$), which is typically considered soluble and available for plant uptake. Total phosphorus (TP) includes the phosphorus that is associated with inorganic or organic particulate matter. Most of



the TP is not readily available for plant uptake. The total phosphorus concentration of a water sample should always be greater than the dissolved orthophosphate concentration, and is a common method to assess water quality lab performance.

Erosion transports phosphorus attached to soil particles. Unlike nitrogen, phosphorus is not particularly mobile in soils, and orthophosphate ions do not leach readily. Excess fertilization and manure productions cause a P surplus, which accumulates in soil. Some of this surplus is transported in soil runoff to aquatic ecosystems. Stream bank erosion and re-suspension of P in stream sediments can contribute significant

portions of the overall P load of streams that drain both agricultural and non-agricultural areas

The EPA has established a Maximum Contaminant Level (MCL) for nitrate in drinking water of 10 milligrams per liter (mg/L) as nitrogen. Phosphorus in water is not considered directly toxic to humans or animals so no drinking water standards have been established for P. Any toxicity caused by P pollution in fresh waters is indirect, through stimulation of toxic algal blooms or resulting oxygen depletion. The EPA recommends that total phosphorus concentrations should be less than 0.1 mg/L in rivers, and less than 0.05

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Reservoirs

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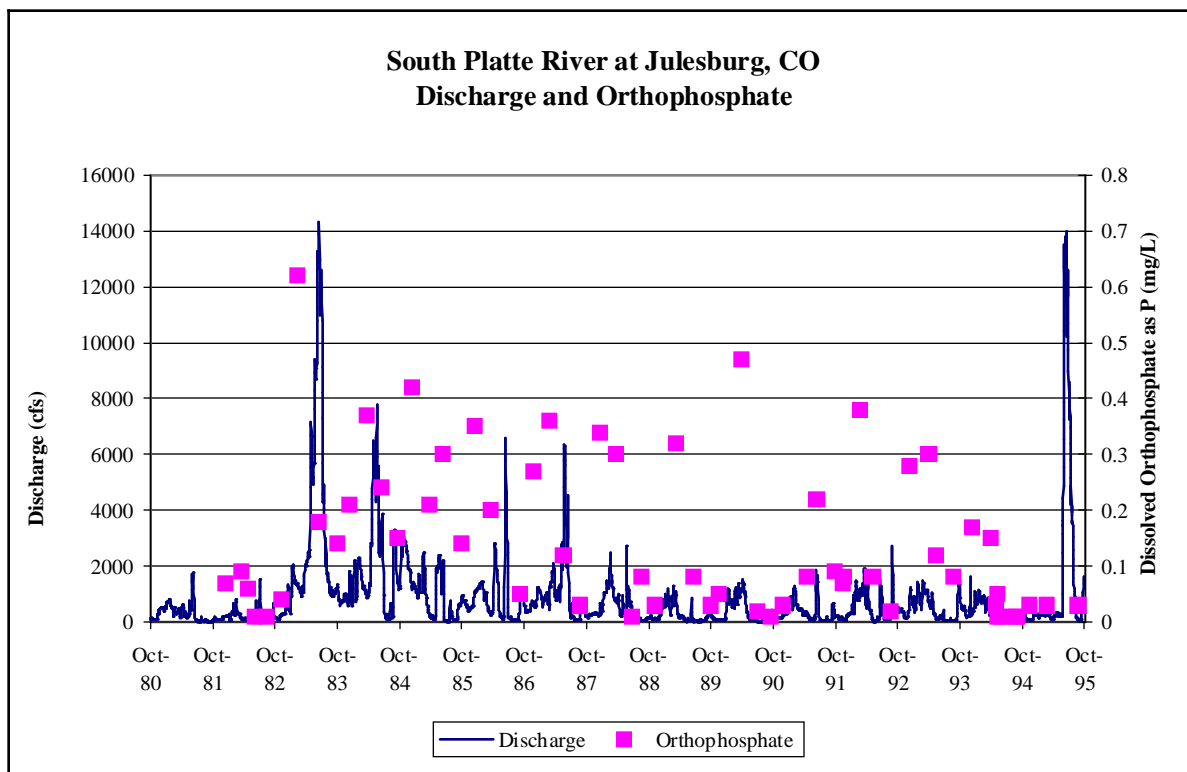
mg/L where rivers enter lakes and reservoirs because concentrations greater than this could contribute to eutrophication (see Table 2). The South Platte River does not always meet the EPA recommendations (Figure 1).

Numerous water quality models use total phosphorus concentrations as a measure or predictor of algal growth or biomass or concentration of chlorophyll. The trophic status (health) of surface water has been categorized by the concentration of phosphorus measured in the surface water (Table 2).

Excess nutrient concentrations may result in eutrophication. Eutrophication means the fertilization of surface waters by nutrients that were previously scarce. Over geologic time, eutrophication through nutrient and sediment inflow is a natural aging process by which warm shallow lakes evolve to dry land. Today human activities are greatly accelerating the process. Excess nutrient concentrations can contribute to excessive growth of algae and other aquatic plants that can cause destruction of habitat and depletion of dissolved oxygen, which usually results in the disappearance of intolerant aquatic insect species and fish.

In freshwater, blooms of cyanobacteria (blue-green algae) are a prominent symptom of eutrophication. These blooms contribute to a wide range of water-related problems including summer fish kills, foul odors, and unpalatable tastes in drinking water. Furthermore, when such water is processed in water treatment plants, the high load of organic detritus reacts with chlorine to form carcinogens known as trihalomethanes. Water-soluble compounds toxic to the nervous system and liver are released when cyanobacterial blooms die or are ingested. These can kill livestock and may pose a serious health hazard to humans.

Figure 1. South Platte River discharge and orthophosphate concentrations at Julesburg, CO.



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Reservoirs

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The effect that reservoirs can have on water quality is evident when nutrient concentrations are compared at sites upstream and downstream from reservoirs. Nutrients in water often decrease significantly while stored in reservoirs. The decrease is attributed to biological uptake of nutrients, suspended sediment settling out of the water column, and phosphorus sorption to sediments. In the South Platte River basin, phosphorus does not significantly decrease after storage. Concentrations of phosphorus, both orthophosphate and total phosphorus in outlet waters approximate the inlet waters. The minimal retention of phosphorus is probably due to the fact that much of the phosphorus load in the South Platte is from WWTPs, and not associated with sediment. The phosphorus inputs exceed plant uptake requirements. The existing sediments in these reservoirs are probably near capac-

ity in terms of phosphorous fixation or sorption, since the inputs literally amount to thousands of kilograms input of P per year. Phosphorus concentrations in reservoir surface waters in the South Platte River



Basin range from 0.05 to 1.0 mg/L, with means often above 0.1 mg/L.

If current practices continue, nonpoint pollution of surface waters is virtually certain to increase in the future. Such an outcome is not inevitable, however, because a number of technologies, land use practices, and conservation measures are available that can decrease the flow of nonpoint P into surface waters.

Phosphorus is a critical element for crop production. Proper management can limit the amount of phosphorus reaching streams,

wetlands, and lakes from agricultural fields. The successful steward of land and water resources will use crop selection, soil conservation measures, nutrient management planning, knowledge of weather patterns and common sense to limit phosphorus loss from agricultural fields.

Phosphorous concentrations in rivers, lakes and reservoirs are directly related to eutrophication of waterbodies. Since most chemical forms of phosphorous are not readily mobile in water, problems with phosphorous and eutrophication can reoccur over several years due to the resuspension of P from the sediments. Since P cannot easily be removed from a waterbody, the best method to help prevent eutrophication is to stop phosphorous from reaching the waters through BMPs.

*John Stednick
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Colorado State University*

Table 2. Definition of lake or reservoir trophic status by water characteristics and TP concentrations.

Trophic status	Characteristics	Total P Concentrations (mg/L)
Oligotrophic	Poorly nourished, clear waters with limited sediment and biological activity	0.000 to 0.010
Mesotrophic	Intermediate productivity and clarity.	0.010 to 0.025
Eutrophic	High nutrient content, water treatment problems with taste and odor.	0.025 to 0.100
Hypereutrophic	Highly productive, murky waters. Cyanobacteria that may produce toxins.	>0.100

Soil Testing For Phosphorus

Extractants for phosphorus may vary, but results break down into similar categories.

Several tests for soil P are commonly used to extract phosphorus to determine fertilizer rate. The different tests can be confusing because they extract different amounts of phosphorus depending on the type of extract used. While many laboratories are able to use different P extractants at their customers' request, they routinely will use only one or two methods that may be suited to their geographical area. It is important for growers to know what type of test was used to extract their soil and to realize that if they send their soil samples to a different lab, a different test may be performed, resulting in values of extractable P that may be different. Regardless

of extractant, the important point is that soil P concentration must be calibrated to crop response. For example, the ammonium bicarbonate-DTPA (AB-DTPA) test may extract 2 ppm P from a soil sample while Olsen's test would extract about 4 ppm P from the same soil. Both soils would be considered low in phosphorus, and the maximum phosphorus rate would be recommended.

Table 3 (page 7) shows the most common methods for phosphorus extraction. The AB-DTPA test and the Olsen test were both developed for high pH soils; however, these extracts have been used successfully on moderately acid soils as

well. The other extractants were developed primarily for acid soils, but some tests such as the Bray-P and the Mehlich extractants have been used on a wide variety of soils of varying pH's. The Olsen method and Bray-P are the more popular tests that laboratories use. The AB-DTPA test was developed at Colorado State University and has been used routinely for soil analysis for the last 23 years. The advantage of the AB-DTPA test is that it also extracts nitrate, potassium, micronutrients, and heavy metals simultaneously. The other methods, with the exception of the Mehlich test, are only used for P extraction.

Although extraction methods vary, they are all calibrated to crop response. Phosphorus fertilizer recommendations for crop growth should be similar in spite of the test used. The difference in P recommendations may be more of a philosophical approach of whether to build-up P in the soil or to add just enough P to satisfy the crop's demand and potential yield goal.

While most soil testing laboratories interpret analytical results to make fertilizer recommendations, it is good to have an idea how the results were derived if you want to compare results between laboratories.

James Self

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Phosphorus Levels In Colorado Soils

Categories low, medium, high, and very high are based on crop response.

Evaluating phosphorus in the soil relative to P fertilizer application is an important part of any P test.

According to the ammonium bicarbonate-DTPA test that is used at the Soil, Water, and Plant Testing Lab at Colorado State University, the critical levels for determining fertilizer application rates have been set at 0-3 ppm P for the low category, 4-6 ppm P for the medium category, 8-11 ppm P for the high category, and greater than 11 ppm P for the very high category.

Each category was determined by calibrating crop response to nutrient rate experiments in the field. The steps in calibration studies are 1) determine the critical levels which are the numbers below which there is a fertilizer response, 2) make comparisons between predicted responses based upon the critical levels and field observed responses, and 3) determine the availability indices and amount of nutrient needed to obtain the maximum yield. The low category indicates that with a maximum

level of P fertilizer applied, there is a high probability of crop response to the added P fertilizer. In the medium category, there would be a moderate probability of response to added P. In the high category there would be a low probability of response, while in the very high category there likely would be no crop response to additional fertilizer.

In the fiscal year of July 1, 1998 to June 30, 1999, the Lab analyzed many surface soil samples sent in by farmers. Of the soils received, 29.4% were in the low category (0-3 ppm P), 26.4% in the medium

category (4-7 ppm P), 14.1% in the high category (8-11 ppm P), and 30.1% in the very high category (>11 ppm P). The percentage of soils testing high or very high in P amounted to 44.2% of the total.

Since a large percentage of soils analyzed were high in P, it is important that agricultural soils are tested routinely for phosphorus to avoid adding unnecessary P fertilizer.

James Self

Table 3. Methods used for extracting soil for phosphorus.

METHODS	EXTRACTANT	SOIL TYPE	CRITICAL LEVELS				
			VL*	L	M	H	VH
AB-DTPA	AMMONIUM BICARBONATE-DTPA	ALKALINE	--	0-3	4-7	8-11	>11
OLSENS P	SODIUM BICARBONATE	ALKALINE	--	0-6	7-14	15-22	>22
BRAY-PI	HYDROCHLORIC ACID/ AMMONIUM FLUORIDE	ACID	0-3	4-7	5-19	>20	--
MEHLICH	ACETIC ACID/AMMONIUM NITRATE AMMONIUM FLUORIDE NITRIC ACID EDTA	ACID	--	<10	11-31	31-56	>56
TOTAL P	NITRIC ACID/PERCHLORIC ACID DIGEST	ALKALINE/ ACID				400-600	

*VL= very low, L=low, M=moderate, H=high, VH=very high

Phosphorus Quiz: True Or False?

- 1) *Phosphorus does not move through the soil.*
- 2) *High pH soils are infinite sinks for phosphorus.*
- 3) *Agricultural runoff does not contain enough P to cause water quality problems.*
- 4) *Erosion control will stop phosphorus losses in runoff.*
- 5) *Soil test P level is a good indicator of P loss hazard.*
- 6) *Manure rates should be based upon N loading.*
- 7) *We don't know enough about agricultural P losses to implement solutions.*

Answers

- 1) FALSE. P can move down through soils. Most of the time, P moves with runoff and erosion. BUT P can leach in soils with low P-fixing capacity, high percolation, or high soil test P. Organic P seems more prone to leaching than inorganic P.
- 2) FALSE. Any soil can be saturated with P. The more lime (or calcium carbonate) a soil has, the more P can be fixed, BUT this fixation is not infinite. When soils are saturated with P, then P becomes more mobile.
- 3) FALSE. We sampled 38 irrigated fields sampled in Colorado in 1998 – 1999, and found total P levels in runoff that ranged from 0.1 - 1.8 mg/L. Total P thresholds are 0.05 mg/L in lakes and 0.10 mg/L in streams.
- 4) FALSE. Runoff P is also a concern. Most P moves attached to soil particles that move in the erosion process, BUT there is still a substantial fraction of soluble P that can move in runoff water. Therefore, erosion control will substantially reduce P loss, but will not stop it completely.
- 5) TRUE, BUT. . . Increasing soil test P increases runoff P, BUT the relationship between soil test P and runoff P is different for each soil type. Transport factors such as slope and irrigation practices have a big influence on this relationship.
- 6) TRUE AND FALSE. When manure rates are based on N loading, overapplication of P occurs. If this is repeated year after year, soil test P levels climb, AND more P runoff will occur.
- 7) FALSE. We know enough about the P problem and how P moves, that we can act now. Let's not wait till the problem is so severe that we have no choices.

Environmental Implications Of Soil Testing For Phosphorus

New tests are available for predicting phosphorus mobility.

Historically, soil testing has been used to evaluate P availability to crops and to make P fertilizer recommendations. Sometimes people use these soil tests to estimate the potential for P runoff. For example, both the new hog regulations and the biosolids regulations use a cutoff of 100 ppm Olsen P (50 ppm AB-DTPA). If a field has an Olsen P level above 100 ppm, it is illegal to apply hog manure or biosolids to that field unless proof is given that P runoff is not occurring.

Research has shown that traditional agronomic soil tests for P are often

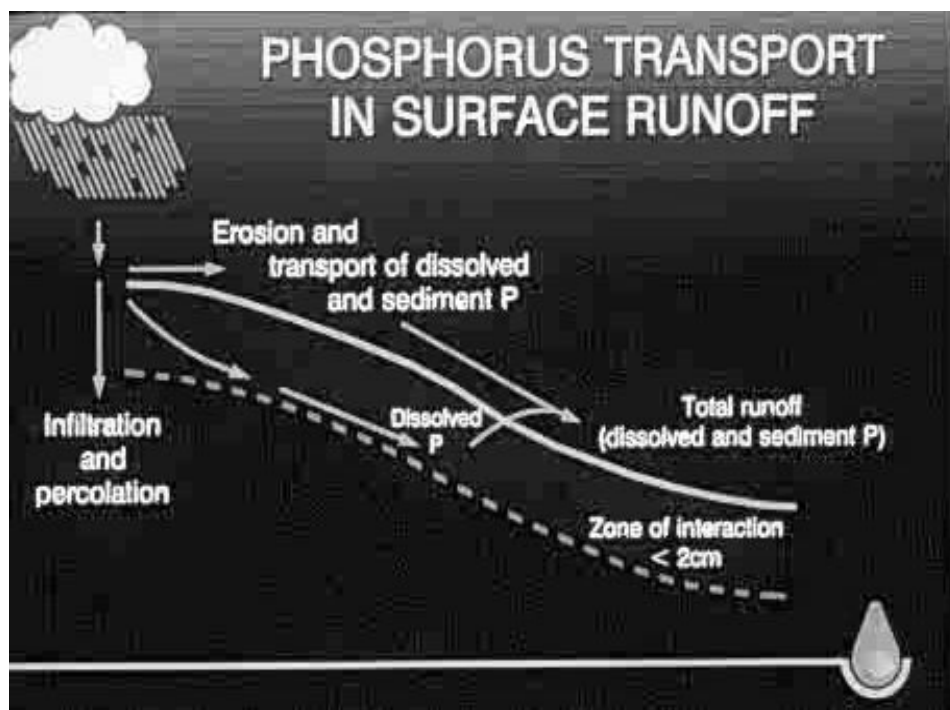
correlated with runoff P levels. However, these relationships are different for different soil types. Some soils bind more P, and some soils are more susceptible to runoff than others.

In the past few years, numerous soil tests have been developed for the purpose of predicting P mobility. One approach is to use water soluble P to simulate the release of P to rainfall and runoff water. Another promising method is called the iron oxide strip method. In this procedure, the potential of a soil to release or "desorb" P is measured. This method is a good

indicator of the biological availability of P to algae in surface waters, but it is a much more tedious method than either the water soluble P test or typical agronomic tests, such as Olsen or AB-DTPA.

Dutch scientists have developed another analytical tool called the degree of P saturation. In this method, the P sorption capacity of a soil is determined, and then the current P status of the soil is presented as a percentage of the total sorption capacity. Unfortunately, this method was developed for acid soils in which the P sorption capacity is determined by the amount of iron and aluminum oxides and hydroxides. In calcareous and high pH soils, on the other hand, the amount of soluble calcium and the amount of lime (calcium carbonate) are important factors in P adsorption. Scientists in the U.S. are currently working on modifying this method so that it can become useful for high pH soils, which are typical in Colorado.

Be cautious about using agronomic soil P tests for predicting P runoff potential. A high level of plant available P is not necessarily equivalent to a high level of environmentally mobile P.



Predicting Phosphorus Pollution Potential

Does phosphorus risk assessment or soil test provide better information?

The key to minimizing agricultural P impacts on surface waters is being able to identify fields within a watershed that are most likely to contribute P to water bodies, and then to manage those areas using BMPs which will reduce P runoff from those sites.

Soil test P levels are one option for predicting P runoff. However, soil tests such as Olsen or AB-DTPA extractants were developed to predict P availability to crops. They were not designed to predict the potential for runoff from soils. Therefore, we have to be careful about interpreting soil test P levels in terms of environmental impact.

Research studies have shown that as soil test P levels increase, the concentration of P in runoff increases. However, the slope of the line is different for each soil, depending on the soil texture, its

ability to fix P, field slope, and management factors that affect residue cover and erodibility (Figure 2).

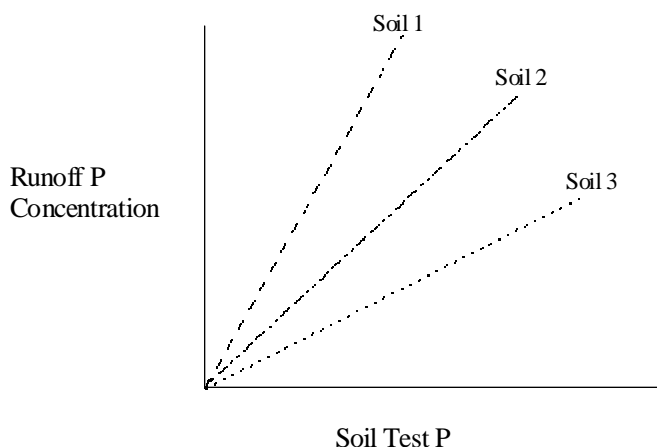
Since the slope of the line is different for each soil, it is impossible to predict runoff P concentration from soil test P unless there is a database on that soil type available which includes the slope and management conditions that you are dealing with. Accumulating such a database will require a huge effort, and Natural Resource Conservation Service (NRCS), Agricultural Research Service (ARS), and land grant universities (including CSU) are involved in this nationwide effort.

The P Index is another tool for predicting P pollution from agricultural fields. The P Index factors in the potential for P transport off-site in addition to the amount of P

present. In other words, P runoff depends on two criteria: how much P is present and the potential for transport of that P into surface waters. Site factors used to characterize P supply include soil test P, manure and fertilizer application rates, and methods of application. Site characteristics used to estimate P transport potential include soil erosion, irrigation erosion (based on flow rate and slope), and runoff class (based on permeability and slope). Each characteristic is rated, multiplied by a weighting factor, and then added together to develop a rating for P runoff risk.

We are working with NRCS to develop a P Index for Colorado. In 1998 and 1999, Nicole Harry, Reagan Waskom, Troy Bauder, Jim Valliant, Wayne Cooley, and I sampled runoff from 38 fields and measured the site characteristics described above and the P concentration in the runoff. Additional factors like length of run (for furrow-irrigated fields) and the use of polyacrylamides were also included. We are currently using this database to develop a P Index specific for Colorado for predicting P runoff from agricultural fields. NRCS intends to use the P Index to evaluate P hazards and to make decisions regarding whether manure application rates should be based on the N or P needs of the crop.

Figure 2. Runoff P concentration for 3 hypothetical soils.



Al-Kaisi leaves CSU-CE to join Iowa State faculty.

Dr. Mahdi Al-Kaisi, CSU Water Quality Specialist for the northeast region is leaving Colorado to join Iowa State University. Mahdi will be an Extension Soils Specialist at ISU and will continue to work on issues related to confined animal feeding, water quality, and soil management. We will miss Mahdi's contributions to CSU's outreach efforts.

New resource materials available through CERC.

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meet. . .



Dean Heil is Assistant Professor of Soil Chemistry in the Soil and Crop Sciences Department at Colorado State University. His research and teaching focus on surface chemistry, colloids, and speciation. Currently, he is engaged in research on remediating lead contaminated soils and transport of metals in biosolids amended soils.

Dr. Heil would be a good resource for those with questions about surface chemistry, colloids, and speciation.

Heil joined the CSU faculty in 1997. He holds the Ph.D. in Soil Chemistry from the University of California, and the M.S. and B.S. in Soil Science from Colorado State University.

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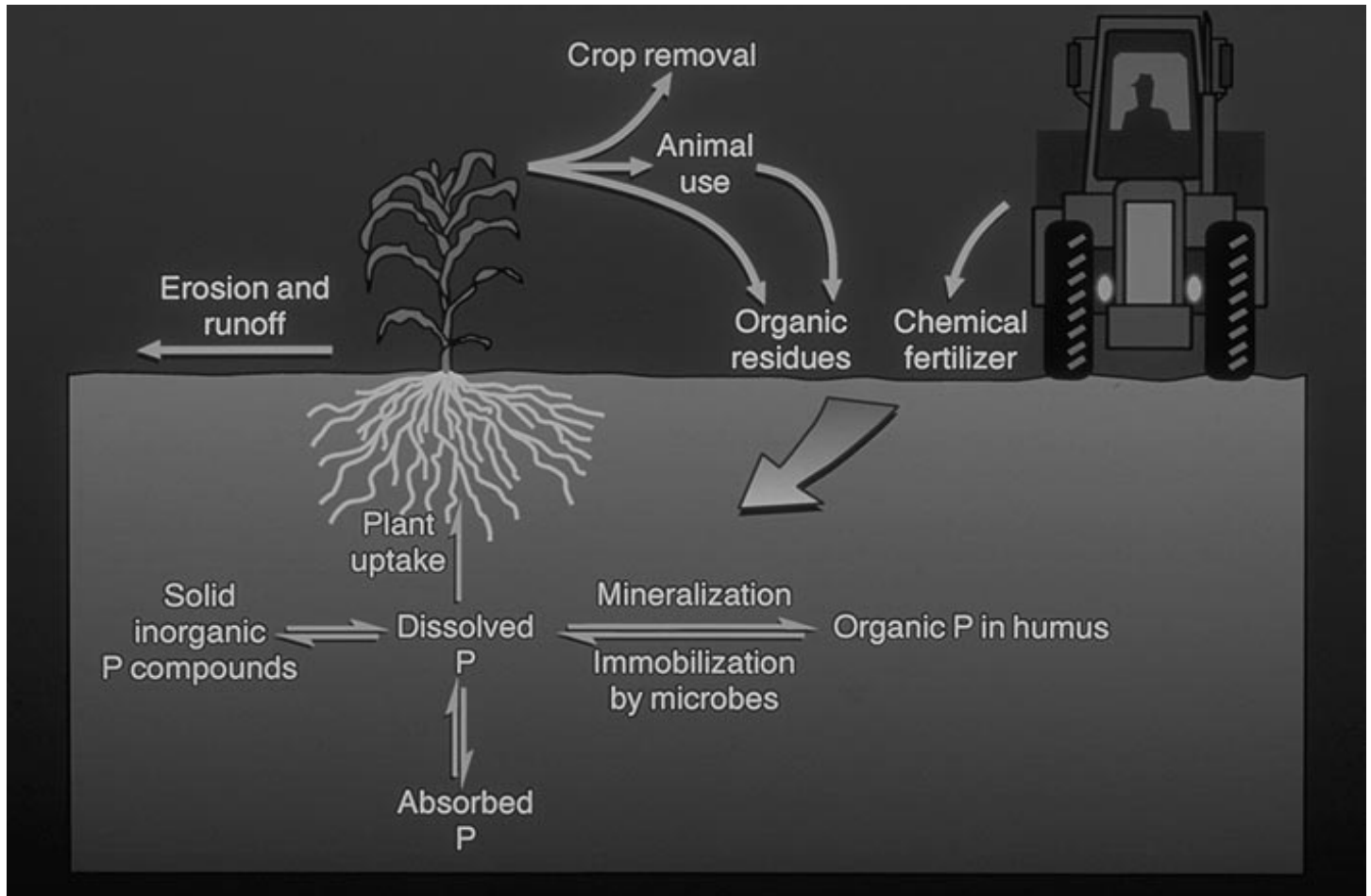
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Reducing Phosphorus Impact On Water

Best management practices address fertilizer, manure, irrigation, and soil.



Reducing P losses from agriculture ultimately requires balancing P inputs with crop P removal, coupled with soil management to retain nutrients. Simply implementing BMPs that reduce soil erosion is not adequate. At high soil concentrations, P will become mobile and can be transported in solution when runoff from rainfall

or irrigation occurs. Both source and transport control strategies must be implemented on fields that drain to sensitive surface water. Fortunately, all fields do not contribute equally to P export from watersheds. Most P export comes from only a small portion of the watershed as a result of relatively few storms or irrigation events.

Managing fertilizer

Phosphorus fertilizer applications at recommended rates can minimize P loss in agricultural runoff via increased crop uptake and more residue cover. Fertilizer application to build soil test levels is no longer a desirable practice. Rather, producers should attempt to optimize crop response by applying

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BMPs

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fertilizer at agronomic rates.

Placement of P fertilizer will influence the amount of P available for transport to surface water. Correct placement of fertilizers in the plant root zone will improve fertilizer use efficiency and seedling vigor, and reduce the amount of P in runoff. Phosphorus fertilizer should not be broadcast on the soil surface without incorporation, except on perennial forages. In established alfalfa stands, P fertilizer should normally not be applied in the late fall or winter when growth is minimal and runoff potential is high. Broadcast applications generally are less efficient and leave more P at the soil surface than banding. Band application at planting is considered the most efficient method for row crops. Subsurface placement is especially important under reduced tillage cropping systems to achieve maximum crop yields.

Variable fertilizer rate management can improve fertilizer use efficiency and economic returns in some cases. While this strategy can be adopted for any fertilized field, it makes the most sense in relatively large fields where the producer has knowledge of how crop yields and soil type vary across the field. To use a variable fertilizer rate strategy:

1) Divide the field into different management units based upon a map of yields and soil types.

2) Soil sample the management units separately.

3) Fertilize each unit according to P soil test level and yield capability.

Managing manure

Manure is an excellent source of P for crop production. However, if manure is not managed properly, runoff may carry both soluble and sediment-associated nutrients to surface waters. Producers need soil and manure analyses to determine the correct application rate based upon crop uptake of N or P. Approximate table values are available for various manure sources, but manure sampling and analysis are the most accurate way to calculate nutrient credit.

As with commercial P fertilizers, manure should be incorporated immediately after application. Injection of liquid manure beneath the soil surface with specialized equipment is also a recommended practice. Unlike commercial fertilizer, the P content of manure can vary significantly. Additionally, N and P contents are not equal. On sensitive fields, manure rates may need to be based upon crop P need rather than N. In these situations, supplemental fertilizer N will be required to meet yield goals. In many cases, the best program is to rotate fields receiving manures to avoid salt and nutrient buildup.

Site characteristics such as land slope, surface residue, and proxim-

ity to surface water must be used to determine which management measures are needed to protect surface water from P enrichment from manure. In some cases, sites with excessive slope or highly erodible soils are not suitable for manure application, even with careful management. Application of manure on frozen or wet soils subject to runoff is not recommended.

Runoff from feedlots and manure stockpile sites also can contribute nutrients to nearby surface waters. Best management practices to reduce runoff impacts include yard shaping, settling basins, diversions, and filter strips.

Managing soil

Since the majority of P leaving a field is bound to sediment, practices that reduce sediment movement offsite greatly reduce P losses. A number of management practices and structures for controlling runoff and erosion are currently available for use. In some cases, there is a trade-off between reducing runoff and increasing deep percolation to groundwater. BMPs for managing surface runoff and soil erosion are listed in Table 4 below.

Buffer strips between erosive fields and surface water can help settle soil sediment and thereby reduce sediment borne P loads.

Managing irrigation

Managing irrigation to reduce P transport is similar to managing irrigation to reduce erosion. Water

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BMPs

(Continued from page 13)

applications should be applied at a velocity appropriate to the slope and length of run that minimizes down cutting. In some cases, it is necessary to split fields into shorter runs to achieve the optimum uniformity without excess velocity. Use of polyacrylimides (PAM) has

been shown to allow producers to increase flow rate while reducing sediment detachment and transport.

Reducing irrigation runoff altogether is the most effective way to reduce or eliminate P movement. Surface irrigation system upgrades such as surge valves and tailwater pits or switching to a properly nozzled sprinkler system will largely eliminate runoff to natural water bodies.

Summary

- ◆ Good P management should balance P inputs and outputs.
- ◆ Fields that are highly erosive and/or are near surface water need more management to reduce P losses.
- ◆ Manure rates should be based upon crop renewal for fields with high to very high soil P test levels that are near surface water bodies.

Reagan Waskom

Table 4. Erosion control BMPs for reducing surface losses from crop fields.

Best Management Practice	Description
Conservation tillage	Cropping system that maintains at least 30% of the soil surface covered with residues after planting.
Conservation cover	Perennial vegetative cover established and maintained on highly erodible lands where other BMPs are insufficient to reduce adverse water quality impacts.
Conservation cropping sequence	Crop rotation sequence designed to increase crop residues on the soil surface to reduce erosion.
Delayed seed bed preparation	Cropping system in which all crop residues are maintained on the soil surface until 3-4 weeks prior to planting the succeeding crop.
Grass filter strip	Permanent sod strip planted at the base of sloping fields or between the field and surface water bodies.
Grassed waterway	Sodded channel that provides a non-erosive outlet for runoff.
Contour farming	Crops are planted on the natural contour of the land to reduce erosion.
Strip cropping	Alternating strips of row crops and solid seeded crops planted on the contour.
Terrace	Earthen embankment constructed across the slope to reduce slope length and runoff velocity.
Diversion	Grassed channel constructed across the slope, uphill of a tilled field, to divert excess water to areas where it can be managed properly.
Sediment control basin	Basins constructed to collect runoff and trap sediments.
Constructed wetland	Artificial wetland created downhill from feedlots and irrigated crop fields where sediment and runoff are collected and assimilated by growing vegetation.
Polyacrylimides (PAM)	Irrigation water amendment that flocculates suspended sediment



websites. . .

<http://www.nhq.nrcs.usda.gov/BCS/nutri/pindex.html>

Contains the NRCS Phosphorus Index data tables. Site will link to state projects as available.

<http://www.nhq.nrcs.usda.gov/BCS/nutri/manage.html#nm>

NRCS Nutrient Management homepage with links to a program to help evaluate nutrient management decisions.

<http://www.ColoState.EDU/Depts/CoopExt/PUBS/CROPS/xcm175.pdf>

Best Management Practices for Phosphorus Fertilization: 6 page booklet published by CSU Cooperative Extension.

<http://www.ppi-far.org/PPIArea/periodicals/ab/ab98/fa98/fa98-2ael.html>

Fall 1998 Agri-brief article explaining phosphorus fixation.

<http://www.ppi-far.org/>

Potash and Phosphorus Institute homepage includes links to phosphorus articles in Agri-briefs, and Site-specific Management Guidelines.

<http://www.ianr.unl.edu/pubs/soil/g601.htm>

Neb Guide, Using Phosphorus Fertilizers Effectively.

<http://www.oznet.ksu.edu/library/crpsl2/mf2321.pdf>

Phosphorus Practices and Principles booklet , 5 pages.

<http://www.ars.usda.gov/is/np/Phos%26Eutro/phos%26eutrointo.htm>

Agricultural Phosphorus and Eutrophication