UNIVERSITY OF MARYLAND
COLLEGE OF AGRICULTURE AND NATURAL RESOURCES

The Agricultural Perspective

Agriculture and Its Relationship to Toxic Dinoflagellates in the Chesapeake Bay

October 16, 1997

Revised November 27, 1997

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BACKGROUND

Although the evidence is circumstantial and inconclusive at this point, it has been suggested that nutrients lost from agricultural operations through runoff and leaching may be partially responsible for the recent outbreaks of *Pfiesteria*-like organisms in the lower Pocomoke River and several other rivers on the lower Eastern Shore. Nutrients enter water from many sources. Nutrients added to land, however, may represent a significant source of aquatic nutrients. Sewage sludge, septic tank effluent, organic manufacturing waste, and animal manures contain high concentrations of nitrogen and phosphorus. Most of this material is recycled onto land for disposal.

For many years the agricultural community has recognized the need to reduce the loss of nutrients from farmland and has implemented several programs to control nutrient loss. Past efforts, while successful, have focused on reducing nitrogen losses. Recent evidence collected by Dr. Frank Coale, of the University of Maryland College of Agriculture and Natural Resources, demonstrates that some soils of the lower Eastern Shore are highly enriched with phosphorus—to the point where soluble phosphorus may now be lost through runoff. This finding is counter-intuitive to previous scientific thought. A change in control practices to reduce losses of soluble phosphorus represents a major shift in paradigm.

In response to a request by Commission Chair and former Governor Harry Hughes, Thomas A. Fretz, Dean of the College of Agriculture and Natural Resources, brought together a panel of regional experts in nutrient and animal management not only to examine the most current information related to nutrient losses, but to develop a strategy for reducing those losses. While the relationship between the outbreak of *Pfiesteria* and nutrient loading into aquatic systems remains unclear, the agricultural community recognizes the need to take action. Thus, a primary goal of this document is to review current practices and recommend methods for controlling losses of nutrients, especially phosphorus, from agricultural land.

This document contains scientific background information for the comments presented to former Governor Harry Hughes and the Blue Ribbon Commission. To the extent possible, we have attempted to discuss the level of uncertainty and the potential for recommended practices to contribute to reducing nutrient losses—especially soluble phosphorus—from land. In addition, we also discuss the length of time (immediate, short term, long term) required for implementing practices.

OBJECTIVES

The objectives of the Agricultural Scientific Advisory Committee were to:

1. Review current State efforts for controlling losses of nutrients from agricultural land.

2. Review and critically evaluate relevant research on nutrient losses from agricultural land.

3. Recommend practices for reducing losses of nutrients, especially soluble phosphorus, from agricultural land.

4. Identify important scientific questions that limit our ability to recommend effective practices.

APPROACH

A group of 10 scientists, chaired by Dean Fretz, met on October 7, 1997, to review relevant issues and to develop a format for completing the assignment. Review and writing teams were established and charged with drafting this document by October 13, 1997. The Scientific Advisory Committee met twice more to review progress and discuss possible recommendations. This document forms the basis of much of Dean Fretz's verbal testimony.

ISSUES AND SOLUTIONS

Land Application Issues

Nutrients, essential for crop production, come from various sources. Most commonly, farmers obtain nutrients from inorganic commercial fertilizers and from organic sources such as animal manures and biosolids from wastewater treatment plants. Generally, inorganic nitrogen and phosphorus compounds are water soluble and readily available to plants. Most organic nutrient sources must first be mineralized or decomposed to become available to plants, although some may contain inorganic forms of nutrients. Mineralization occurs when moisture and soil temperature are optimal for the growth of microorganisms, which must actively convert these organic forms to inorganic forms.

The movement of nitrogen and phosphorus through soil can differ dramatically. We have long understood that if nitrogen is converted to the highly water soluble nitrate-nitrogen form, and is not used during plant growth, it can move through the soil-water system and be vulnerable to leaching into the groundwater. In contrast, however, the general understanding has always been that phosphorus does not move through the soil-water system. Most phosphorus applied to soils was thought to be readily converted into insoluble forms associated with the iron, aluminum, and calcium ions in the soil system; it was only transported from the field through soil erosion. Recent research, however, demonstrates that soils amended with large quantities of organic or inorganic phosphorus may generate significant amounts of soluble phosphorus that can be readily transported by surface runoff water, even when erosion losses are minimal.

When we use organic sources of nutrients, the ratios of nitrogen and phosphorus do not usually correlate with the crop's actual nutrient needs. When we apply commercial fertilizers, we can tailor the ratios of nitrogen and phosphorus to meet the crop's nutrient needs. If we apply an organic nutrient to meet the nitrogen needs of the crop, what generally happens is we overapply phosphorus. If we apply an organic source to meet the crop's recommended phosphorus needs, organic material application rates are necessarily lower and underapplication of nitrogen occurs. We must then apply additional nitrogen from other sources—generally, commercial nitrogen fertilizers. Thus the challenge is to develop systems that allow the optimum use of organic sources of nutrients while maintaining environmental integrity.

Nutrient losses are associated with water movement. Nutrient loss from the field occurs either through surface water runoff or when nutrients leach down through the soil column. The local hydrology is very important when assessing and controlling non-point source nutrient pollution. Local variations in hydrology often preclude a singular approach to nutrient management and control. Rather, we need to develop a range of best management practices (BMPs).

Issues Specific to Nitrogen

Except for legumes, most crops require nitrogen fertilization. We recognize that crop systems are relatively inefficient in using applied nitrogen. When we apply nitrogen as a nutrient, losses do and will occur. Even under natural systems, nitrogen is lost from the soil.

Nitrogen losses, other than by crop removal, occur in the following ways:

a) inorganic and organic forms of nitrogen compounds are lost through surface water runoff and the related movement of particulate organic materials and through soil erosion;

b) soluble compounds (primarily nitrate-nitrogen) leach through the soil-water system, if the nitrogen is not used by the crop or if the nitrogen migrates below the root zone of the crop; and

c) inorganic nitrogen compounds vaporize into the atmosphere.

The purpose of current management systems for limiting nitrogen losses is to increase the efficiency of nitrogen use and to optimize nutrient input. Best management practices for obtaining these goals are: setting realistic yield goals; following recommendations for nutrient needs; increasing the adoption of winter cereal cover crops for water quality enhancement; testing manure and biosolids; applying nutrients at the correct time and using the correct methods; in-season soil and plant tissue testing, such as the presidedress nitrate test for corn; and using efficient crop rotations. While many farmers are following these BMPs, their wider adoption should further limit nitrogen losses from the agroecosystem. Adopting nitrogen-management BMPs, however, may increase operation and crop production costs.

Issues Specific to Phosphorus

Growing crops generally use small amounts of phosphorus relative to nitrogen. However, either through the continued application of commercial phosphorus fertilizers, the disposal of animal waste, or the calculated application of animal manures and biosolids through nitrogen-based nutrient management plans, the phosphorus content of many Maryland soils may become very high. While most of this phosphorus is generally in rather insoluble forms, losses may occur.

Phosphorus losses from agricultural systems, other than by crop removal, generally occur through the following pathways associated with surface water runoff:

a) particulate losses either as phosphorus absorbed into soil particles or organic materials, and/or

b) soluble inorganic and organic phosphorus compounds.

Little phosphorus is lost through leaching into groundwater. However, recent research indicates that the potential for leaching losses may exist on sandy soils with high phosphorus contents.

To control phosphorus losses, we generally recommend the BMPs currently in use to limit soil erosion. These are, among others: no-till farming, contour/strip cropping, grass waterways, buffered streams, and related structural controls.

Soil test–based recommendations for applying phosphorus take into account the phosphorus status of soils and, in turn, only recommend phosphorus applications on soils with low or moderate phosphorus contents. Farms using inorganic fertilizers as a nutrient source generally follow these recommendations. Farms using organic materials (e.g., manures) as a fertilizer source often overapply phosphorus.

Before we understand the true ecological impact of phosphorus overapplication, we must establish a better understanding of the potential for phosphorus transport from the field to surface water and the ultimate bio-availability of the transported phosphorus. Without a broad agroecosystem approach to minimizing phosphorus enrichment of surface waters, singularly focused management practices may be counterproductive. For example, no-till farming is extremely useful in reducing soil erosion and particulate phosphorus movement. However, it may actually increase the amount of soluble phosphorus lost in surface water runoff. Other options for managing phosphorus include BMPs that reduce soluble phosphorus losses through plowing previously no-till or minimum-tilled soils and incorporating manure upon application. We must, however, carefully weigh these suggestions against the increased risk of soil erosion and particulate losses and the increased cost of labor, fuel, and machinery.

Nitrogen- and Phosphorus-based Nutrient Management Planning

Realizing that both nitrogen and phosphorus are nutrients of concern for the Chesapeake Bay ecosystem, the current University of Maryland/Maryland Department of Agriculture Nutrient Management Program concentrated on managing nitrogen, which at the time the program was initiated in 1989, appeared to be the more problematic of the two nutrients. Also, the established thinking maintained that controlling soil erosion losses through soil conservation practices would also control phosphorus losses.

We have made progress in reducing both nitrogen and phosphorus inputs. These reductions are the result of reductions in both nitrogen and phosphorus application recommendations and farmers' realization that manures should be used as a nutrient source rather than treated as a waste disposal problem. How these reductions have translated into water nutrient-loading reductions remains speculative, since monitoring of nonpoint source inputs has been minimal.

The emphasis on nutrient management planning has been based, in most part, on optimizing nitrogen inputs. On farms where animal manure is the major or only fertilizer source, this system has allowed phosphorus to be overapplied. Nitrogen-based plans have made use of animal wastes, been cost effective, and reduced nitrogen application to land. However, this has resulted in overapplication of phosphorus. These applications frequently occur on soils with an already extremely high phosphorus content caused by past applications of manure of a much higher phosphorus content. This overapplication increases the potential for phosphorus to move from farmland to nearby water, especially from land maintained under reduced-till cultivation.

It is possible to develop nutrient management plans for farms by using either nitrogen or phosphorus as the limiting nutrient. Nitrogen-based nutrient management planning may continue to be the most effective one for many farms. Farms where nitrogen-based plans are recommended need to implement improved monitoring of pre-, post-, and in-season soil nitrate-nitrogen levels. Farmers need to calibrate and use existing and evolving nitrogen management tools—corn stalk nitrate-nitrogen testing, corn leaf chlorophyll meter analysis, preplant soil nitrate-nitrogen testing, and in-season soil nitrate-nitrogen testing for wheat. Overall, crop nitrogen management will need to be intensified. Winter cereal grain cover crops should be effectively managed on the maximum possible acreage following summer annual crop production where land would otherwise remain fallow.

Many instances will require using nutrient management plans based on phosphorus. These plans would be environmentally sound and should begin to limit both phosphorus and nitrogen enrichment of the associated water bodies. However, this type of planning would have a very serious and potentially expensive impact on farms that generate or use animal manures. Currently, most of the soil in certain regions of the State has a high phosphorus content. We should limit additional phosphorus applications, therefore, to the rather small land base with soil of a medium to low phosphorus content. Thus, phosphorus-based planning would require a land base that is unavailable locally, requiring increased on-farm storage capacity, transporting and marketing manures far from the point of generation, and developing alternative manure uses. Phosphorus-based plans would also require importing additional synthetic fertilizer nitrogen sources, since the nitrogen available from manure under a phosphorus-based plan would likely be inadequate for most crops.

To illustrate the magnitude of the impact of phosphorus-based nutrient management plans, we examined the effect of the impact on a 1,000-acre farm (500 acres of corn, 500 acres of soybeans) with four poultry houses producing a total of 660,000 broilers per year. We compared the economic consequences of the current situation to the case where the farmer is unable to apply poultry litter to the corn. The farmer must bear the cost of disposing of the litter and purchasing and applying inorganic nitrogen and potassium for crop production to replace the nitrogen and potassium from the poultry litter. Based on 1996 corn budgets and prices, the net income per acre of corn is $161.75 if poultry litter application is allowed. This decreases to $116.77 if the poultry litter application must be replaced by inorganic fertilizer. Thus, the net income from corn production to our hypothetical farm is reduced by $22,500.

The cost of transporting the litter out of the region is based on a trucking cost of $0.16 per ton per mile (these costs may be lower for long hauls, but we do not consider handling costs to load, unload, and store the litter). For illustrative purposes, we assume the litter is transported 200 miles. Our hypothetical farm produces 792 tons of litter. Thus, the transportation costs are $25,340. If the litter is sent to a region where inorganic phosphorus is currently being applied, the litter can be used in place of the inorganic phosphorus, saving that grower $45 per acre for phosphorus, nitrogen, and potassium. This translates into a value of $28.40 per ton of litter. The market value of the litter, therefore, lowers the net cost of disposal by 89 percent to $2,850. Combined with the increase in corn production costs, the net income loss to the poultry/corn/soybean operation is $25,350 per year.

Adopting phosphorus-based nutrient management plans would affect the farm enterprise through increased operation and crop production costs. Major changes to current farming practices such as adopting phosphorus-based nutrient planning and the resulting import of fertilizer nitrogen and export of manures, can have a significant impact on the profitability of any farming system. Thus, it is imperative that if phosphorus-based planning is to become a reality, it be carefully targeted to the locations at greatest risk for phosphorus losses in farmland runoff and be implemented over a period of time sufficient to enable the farming community to adjust to this very different set of management circumstances. This will also require finding alternative uses and remediation strategies for existing animal waste. Any recommendations given consideration must be done concurrently with full development and implementation of cost-effective alternatives.

Land Application Solutions

1. Establish a State-supported program to facilitate implementation of the use of winter cereal cover crops for water quality and erosion control.

2. Establish a scientific advisory group to advise Maryland's Department of Agriculture on the judicious and incremental transition to phosphorus-based nutrient management planning.

3. Target phosphorus-based nutrient management plans to fields with a very high potential for phosphorus loss, as defined by fields with "excessive" soil-test phosphorus levels that also have a "very high" Phosphorus Index rating.

4. Provide the cost share for the cost difference between following a phosphorus-based plan and a nitrogen-based plan.

5. Reliably evaluate the effectiveness of acceptable agronomic practices to control or minimize surface and subsurface losses of nutrients from agricultural systems. This would include impacts of tillage. Incorporation through tillage needs to be used more intensively in land application of poultry litter to distribute the phosphorus levels in greater soil mass. With conventional no-till and minimum-till systems to reduce erosion, we have concentrated the phosphorus levels in the upper soil horizons. Plowing in litter at the time of application would distribute the phosphorus more uniformly throughout the root zone, and could to some degree reduce runoff of soluble P.

Animal Feeding and Management Issues

Feeding and managing animals affects manure quality and, potentially, the extent of nutrient losses from the farm. Two issues are important: improved management decreases the nitrogen and phosphorus content of manure; and improved management decreases feed nutrient requirements and cropland acres needed to support a given level of animal and plant production.

A significant portion of manure nitrogen and a highly variable portion of manure phosphorus are lost from the farm once they are applied to crops. Therefore, reducing the amount of manure nutrients directly decreases the subsequent nutrient losses. Ultimately, it is much more logical to reduce the production of a waste product than to find alternative solutions once the waste has been generated.

Poultry Industry

Approximately 625 million birds (three billion pounds of meat) are raised each year on the Delmarva Peninsula. Assuming these flocks are fed according to the National Research Council recommendations, 53 million pounds of manure N and 22 million pounds of manure P will be excreted per year. Poultry farming therefore represents one of the significant sources of nutrients that have a potential impact on water resources.

The phosphorus content of plant-source feed ingredients is considered to be only 30 to 40 percent available for use by nonruminants such as poultry and swine. The remaining 60 to 70 percent is bound in the form of phytate phosphorus, which requires the enzyme phytase to break down to forms of phosphorus available to animals. Nonruminants do not secrete the phytase enzyme and therefore any dietary phosphorus in the phytate form will pass through the intestines and into the animal's manure. Typically, because of this low availability of feed grain phosphorus, supplemental inorganic phosphorus, such as dicalcium phosphate, is added to nonruminant diets to meet the animal's available phosphorus requirement for maximal production.

Poultry manure accumulates in the bedding of the poultry house during a period of several years. As manure accumulates, so do the nutrients. Nitrogen levels stabilize after the third flock, but phosphorus and potassium levels continue to increase with each flock produced. The clean-out and storage of bedding from poultry houses represent a significant source of the nutrients applied to land. Complete housecleaning occurs every two to three years, but manure sheds were designed for 180- to 210-day storage. Manure disposal, whether on the land, or via an alternative technique, must be available for much of the year.

Poultry Solutions

1. Phytase is the enzyme that converts unavailable organic phosphorus into a form that poultry can use. Commercial phytase is presently available. Phytase can be sprayed onto poultry feed, reducing the amount of inorganic phosphorus added to feed. The use of phytase should reduce the amount of phosphorus in manures. A program is needed to increase the use of phytase in feeds and therefore reduce supplemental phosphorus feeding and manure P output by 20 to 25 percent. Further research is needed to examine phytase stability and feed processing to improve its use in the field. Technology problems involve uniformity of application to pelletized feed but should be worked out quickly. When implemented, the technology will have immediate impacts.

2. Commercially available low phytic acid corn will be available in the year 2000. Use of this corn in feed mixtures should reduce the amount of phosphorus added to feed. This results in a concurrent reduction in the phosphorus content of manure. Programs could be established to encourage the use of low phytic corn as soon as it is available to farmers. This technology will likely result in some increased grower cost at the time of seed purchase. Any seed with intrinsic properties that must be identified and maintained in the marketplace will cost more. Also, there will be increased costs to the feed mill operators, as the grain will require identity preservation in the marketplace before being used to make feed. Impacts are likely to be significant.

3. Long-term research is needed to develop ways to improve the efficiency of nutrient use by broilers and layers.

4. Programs could be established to encourage whole house year round use of litter treatments—for example, iron-based products to stabilize manure phosphorus into environmentally inactive forms.

Alternative Uses of Manure

Issues

Many of the lower Eastern Shore counties have inadequate cropland available for efficient utilization of manure phosphorus, therefore, alternative disposal options are needed. It is critical to develop alternatives to the common practice of applying manure to land. Ideally, it is important to transport nutrients to areas of the state or region where soils do not contain excessive concentrations of phosphorus and phosphorus inputs are necessary for optimum crop production. Distribution is not so much limited by lack of available technology but rather by the economics of transporting manure long distances.

Composting can be defined as a controlled decomposition of organic materials. By providing a proper environment through a proportional allocation of ingredients, microorganisms will, over time, change the form of the organic material into a stable humiclike material. During composting, temperatures will reach 145 to 160 °F if the proper environment is provided. Common pathogenic organisms will be destroyed at the elevated temperatures. In addition to pathogen control, composting organic material such as broiler litter will minimize the odor from the product. Deodorizing broiler litter through composting will enhance its market potential.

After the compost is cured, it can also be applied to the land as a soil amendment, or it can be enhanced with either inorganic or organic nutrient sources to develop a value-added compost of known and marketable fertilizer value. Specialty products could be developed using broiler litter compost as a base. Pelletizing the compost will increase its density and assist with proper application.

Once pelleted, compost could be readily used in a variety of markets including golf courses, nursery crops, container-grown nursery crops, sod production, lawns and gardens, landscaping, silviculture, and median strips and ramps on freeways. This will, however, require considerable market analysis and development.

Burning manures is another disposal option. In the early 1980's, Delmarva Power burned broiler litter in their Indian River Generation Facility at Millsboro, Delaware. Nitrous oxide (NO_x) emissions and a constant litter supply were problems. However, the facility has been upgraded since then and NO_x emissions may not be a problem, today. Even today, however, litter supply remains a problem. The BTU value of broiler litter is about 6,800 BTU's per pound at 30 percent moisture in a large fluid bed burner. The ash content for broiler litter is approximately 11.3 percent. This shows a large volume and weight reduction. Burning raw litter in small on-farm furnaces has presented some problems such as slag formation because of incomplete combustion, odors, particulates, and loading difficulties. Poultry litter as a fuel is used in the United Kingdom. This practice is an environmentally acceptable alternative to land filling. Therefore, broiler litter as a feedstock in the production of heat or electrical energy is feasible and technically possible.

Adequate litter supply, proper combustion equipment and a use for the energy generated have to be considered in designing a proper system. One fluidized bed furnace is under construction on the Lower Shore for use in a poultry production operation. A third boiler unit is being designed for the Eastern Correctional Facility by Maryland Environmental Services, who are considering broiler litter as a fuel feedstock. Ash from burning broiler litter may be used to make artificial soils, as a component of a fertilizer mix, or added to feed as an ingredient for poultry rations.

Solutions

1. Expand efforts to distribute manure to areas of low manure availability and low soil phosphorus concentrations. This remains a possibility, however, we must raise a concern with regard to biosecurity. Transporting raw litter will be viewed as a possible means of spreading avian pathogens and for that reason composting or heat-treating is preferred. Transport to new markets out of the production region may offer up the greatest opportunity for reducing the application of poultry litter on land already high in phosphorus.

2. Conduct research to examine the potential for the burning and energy recovery of manures. Burning efficiency must be investigated, as well as the availibility of the residual phosphorus and metals in the ash.

3. Research on composting, post-compost processing, and compost market potential is also needed.

4. Develop pelletized fertilizer products. A number of products are currently in the marketplace that are manufactured from poultry waste (e.g., Nutri-Mate from Alabama which is shipped to Australia).

Remediation Issues

Regardless of any other measures either to reduce the phosphorus content of manure or to find alternative uses for manure, these actions will have no effect on soils that already have high phosphorus levels and are at risk for phosphorus losses to the surrounding environment. However, remediation of high-phosphorus soils has never been implemented on a large scale. Hence, no standard practices exist; the concepts presented are theoretically viable. As previously noted, many soils within Maryland, and especially the Pocomoke drainage basin, contain very high phosphorus levels, which may restrict any further land application of manure. Remediating phosphorus-enriched soils includes: removing phosphorus from the soil; or phosphorus immobilization by making the soil phosphorus unavailable for transport to surface waters without removing it from the soil. Remediation assumes that subsequent farming practices will add phosphorus in levels that plants can utilize, precluding phosphorus buildup of the scale seen on the Lower Shore in the past 60 years.

The only practiced removal technique is through the use of crops. Growing crops without adding phosphorus provides an income source (or at least a net cost decrease) and leaves the soil undisturbed. It will require the application of nitrogen, which is an expense to the farmer, as well as having a pollution potential of its own. Plants accumulate phosphorus at differing rates and the current wisdom indicates that the dominant factor in phosphorus removal is the amount of plant biomass removed and exported. Hence, independent of phosphorus accumulation rates, an alfalfa crop removes more phosphorus than a soybean crop because the entire plant is removed when alfalfa is harvested. An important advantage of mining phosphorus through crop removal is that it can be accomplished entirely by the individual farmer and requires no additional equipment. Estimates vary, but returning a field with excessive soil phosphorus levels to agronomic levels of phosphorus could require from 20 to as much as 100 years, depending on the initial phosphorus level and the crop used for mining the phosphorus. This time frame is of concern and the economic implications to the individual farmer have not been explored.

A novel variation of mining phosphorus through crop removal, called phytoremediation, is being explored for removing inorganic contaminants from soil. Phytoremediation, or "Green Remediation" uses unusual plants that have developed the ability to concentrate high levels of elements, usually heavy metals, in plant tissue. The primary limitation of phosphorus phytomining is no one has identified reliable phosphorus hyperaccumulators. Although it is likely such hyperaccumulators exist in nature, a concerted effort is first required to identify and collect these plants. These plants could be grown on soils with a high phosphorus concentration. After several years, the soil phosphorus would be low and nutrient losses would not be of concern.

Conceptually, a single chemical treatment of phosphorus-enriched soils would be sufficient to change the relatively mobile forms of phosphorus to stable and far less mobile mineral form. The impact of this treatment on soil pH, nutrient availability, and the ecosystem in general is unknown. There are technological questions concerning application uniformity and treatment efficiency. The economics are not documented.

Tillage, a second immobilization technique, would place the phosphorus-rich surface soil well below the surface and out of reach of surface runoff water, hence effectively stopping surface transport of phosphorus. The best scientific judgment is that leaching through the soil column would not be significant. The phosphorus would be below the surface but still within the root zone, enabling it to be taken up by plants over time. One major concern is that the soil that would be brought to the surface must be equally good for crop production as the original surface soil or it would create a permanent liability for the farmer. Furthermore, the subsurface soils that will be brought to the surface must also be low in phosphorus or tillage will have no impact. The ramification of this is that extensive soil testing of the deeper soil would be necessary prior to performing tillage, and it would not be suitable on some farms. The efficiency of tillage with respect to phosphorus in runoff is unknown, but this reclamation technique holds promise.

Off-field treatment, it can be argued, is not true remediation, but it does have the potential to result in an immediate change in the quality of surface-drained waters. A portion of the lower Eastern Shore is drained by field drainage ditches. Collector drainage ditches then flow into the closest tributary. In soils where soluble phosphate is reaching drainage ditches, it is feasible to chemically precipitate the phosphorus out of the drainage water prior to allowing water to enter a major surface tributary. The ditch treatment concept is to partially fill a length of collector ditch with crushed limestone and create a flow-through treatment system.

Calcium carbonate dissociates and eventually combines with phosphorus to form a very stable form of phosphorus. This approach requires activity only in the collector ditches and permits the continued water table depression that the ditches were designed for in the first place. The cost of crushed limestone is minimal compared to many reclamation options. However, we do not understand the chemical dynamics well enough to predict where the phosphorus would precipitate out. This is a realistic tool to explore for some site-specific applications.

Solutions

1. No remediation technique is understood well enough to endorse without qualification. Therefore, we need to carry out research and demonstration projects before wide scale implementation of remediation practices.

2. Tillage holds potential for acceptance because suitable equipment is widely available and the concept is easily understood. Tillage is appropriate for flat land that has been in no-till cultivation for many years and where manure has been used long enough that soil phosphorus concentrations are high. Intensive soil testing must be done to the depth which the soils will be plowed.

3. Where onsite remediation is not viable, we should consider offsite effluent treatment if water quality sampling indicates significant levels of phosphorus are entering the water system from drained land. However, prior to implementation, additional work is required to assess many of the physical parameters related to this process.

4. There are too many gaps in our knowledge of chemical immobilization and phytoremediation for us to recommend them today. Further, many uncertainties related to the effects on soil chemistry require resolution before we can recommend this practice.

ECONOMIC CONSIDERATIONS

Each of the strategies for reducing nutrient losses from agricultural land will have an economic consequence that must be addressed. The technical solutions presented here each have costs that may be borne by the grower, the integrator, or the consumer. There may also be administrative and enforcement costs associated with a particular action. Additionally, industry and consumers will adjust their behavior when faced with higher costs and new regulations. When poultry prices rise, consumers adjust by purchasing other products. When farming costs rise, there are a number of possible responses. If farming costs rise in one particular region relative to other growing areas, the competitiveness of that type of farming in the region is eroded. Farmers may make less profit, switch to other crops, or the convert the land from farming into some other use. This scenario is clearly contrary to protecting environmental quality and the Governor's Smart Growth Initiative in particular.

The higher cost of poultry production that would result from many scenarios may result in less poultry production in Maryland. A study of the economic impact of the Delmarva poultry industry conducted by the Department of Agricultural and Resource Economics estimated that just a 4 percent decline in Maryland's poultry production would result in an annual loss of $74 million in economic output in the state, a $29 million loss in personal income and business profits, and a loss of 880 jobs. Some of this loss would be ameliorated as the economy adjusted over time.

APPENDIX

Committee Members

Dr. Thomas A. Fretz, Dean of the College of Agriculture and Natural Resources, is also Director of the Maryland Agricultural Experiment Station and the Maryland Cooperative Extension Service. Dr. Fretz chaired the committee and will make the oral presentation to the Blue Ribbon Panel.

Dr. J. Scott Angle is Associate Director of the Maryland Agricultural Experiment Station and Professor of Natural Resource Sciences. During the 1980's he conducted extensive research on leaching and runoff losses from agricultural systems, including turfgrass, no/conventional-till corn, tobacco, and forested areas. More recently his research has focused on the remediation of contaminated soils.

Dr. James C. Wade, Associate Director of the Maryland Cooperative Extension Service and Professor of Agricultural Resource Economics, provides valuable input on the economics of recommendations affecting the poultry industry.

Dr. Lewis E. Carr, of the Department of Biological Resources Engineering, is internationally recognized for his work on the beneficial use of poultry wastes. He was responsible for developing and promoting the composting of dead birds—a practice many farmers on the Delmarva Peninsula follow.

Dr. Gary K. Felton, of the Department of Biological Resources Engineering, has been involved in agricultural nonpoint pollution research and extension since 1977. He has particular expertise on the impact of agriculture on groundwater resources.

Dr. Frank Coale is Associate Professor of Soil Fertility in the Department of Natural Resource Sciences and Landscape Architecture. Recognized as an expert on phosphorus in soils, he was one of the first investigators in the United States to note that soils fertilized excessively with phosphorus could lose soluble phosphorus through runoff.

Dr. Tom Simpson, Professor of Soil Science and Coordinator of Chesapeake Bay Agricultural Programs, is an expert on the impact of agricultural practices on water quality. He is also a leader in policy issues relating to agriculture and water quality.

Dr. Richard Weismiller is Chair of the Department of Natural Resource Sciences and Landscape Architecture. He is also a Professor of Soil and Water Resource Management with expertise in nonpoint pollution from agricultural lands and nutrient management.

Dr. Russell Brinsfield is Center Director for the Wye Research and Education Center. He is recognized for his work in nonpoint pollution, especially on the use of cover crops to reduce nutrient losses from agricultural land.

Dr. Jeannine Dennis-Harter, Professor of Poultry Nutrition at the Eastern Shore Campus, is an expert in the nutrition of poultry, with special emphasis on reducing nutrient inputs into feed.

Dr. Richard Kohn is Assistant Professor of Animal and Avian Sciences. His area of specialization is animal nutrition, and he has developed an internationally recognized model for demonstrating the flow of nutrients on dairy farms.

Dr. Doug Lipton, Associate Professor of Agricultural and Resource Economics and Director of the Maryland Sea Grant Program, is a state leader on issues related to aquatic resources and an expert in assessing the impact of agriculture on Chesapeake Bay fisheries.

Dr. Jim Hanson, Associate Professor of Agricultural and Resource Economics and Assistant Director for the Cooperative Extension Service, is recognized as an expert in farm economics and the impact of farming practices on revenue and profit.

Dr. Doug Parker, Assistant Professor of Agricultural and Resource Economics, is involved in agricultural production and water quality issues.