Introduction

Is manure an environmental risk or benefit?

Phosphorus (P), an essential nutrient for crop and animal production, can accelerate freshwater eutrophication, now one of the most common water quality impairments in many developed countries. Recent outbreaks of harmful algal blooms (for example, *cyanobacteria and Pfiesteria*) have increased society's awareness of eutrophication and the need for solutions, the concentration of specialized farming systems has led to a P transfer from grain- to animal-producing areas. This transfer has created regional surpluses in P inputs as fertilizer and feed, built up soil P levels in excess of crop needs, and increased the loss of P from land to water. Recent research has shown that this loss of P in both surface and subsurface flow from watersheds originated from only a small area of a watershed during a few storms. These areas are where high soil P or P application as fertilizer or manure coincide with areas of high runoff or erosion potential. The overall goal of efforts to reduce P loss to water should be to balance P inputs and outputs at farm and watershed levels, while managing soil and P in ways that maintain productivity. Management strategies that minimize P loss to water may involve optimizing P-use efficiency, refining animal feed rations, using feed additives to increase animal absorption of P, moving manure from surplus to deficit areas, and applying conservation practices, such as reduced tillage, buffer strips, and cover crops, to critical areas of P export from a watershed. As issues related to P management are discussed in this lesson, producers are encouraged to evaluate their own P-related risk on current land application sites. This can be done with the aid of the Environmental Stewardship Assessment (P Index, Appendix A) and Regulatory Compliance Assessment (Appendix B)

Phosphorus [is] an essential nutrient for crop and animal production…

Phosphorus and Water Quality Impairment

Since the late 1960s, point sources of water pollution have been reduced due to their ease of identification. In some areas, however, the relative contribution of agricultural nonpoint sources to remaining water quality impairment has increased. Besides soil and pesticide loss from agriculture, most water quality concerns center on nonpoint transport of the nutrients P and nitrogen (N), which are essential inputs for optimum crop and animal production.

Recent assessments of water quality status have identified eutrophication as one of the main causes of water quality "impairment" in the United States (U.S. Environmental Protection Agency 1996, U.S. Geological Survey 1999). Eutrophication is the natural aging of lakes or streams brought on by nutrient enrichment. This process can be greatly accelerated by human activities that increase nutrient loading rates to water (Figure 34-1). While P and N contribute to eutrophication, P is the primary agent in freshwater eutrophication, because many algae are able to obtain N from the atmosphere (Carpenter et al. 1998, Schindler 1977). Thus, controlling eutrophication mainly requires reducing P inputs to surface waters.

…eutrophication [is] one of the main causes of water quality impairment in the United States…

Eutrophication restricts water use for fisheries, recreation, industry, and drinking, due to the increased growth of undesirable algae and aquatic weeds and oxygen shortages caused by their death and decomposition (Table 34-1). Also, many drinking water supplies throughout the world experience periodic massive surface blooms of *cyanobacteria* (Kotak et al. 1993). These blooms

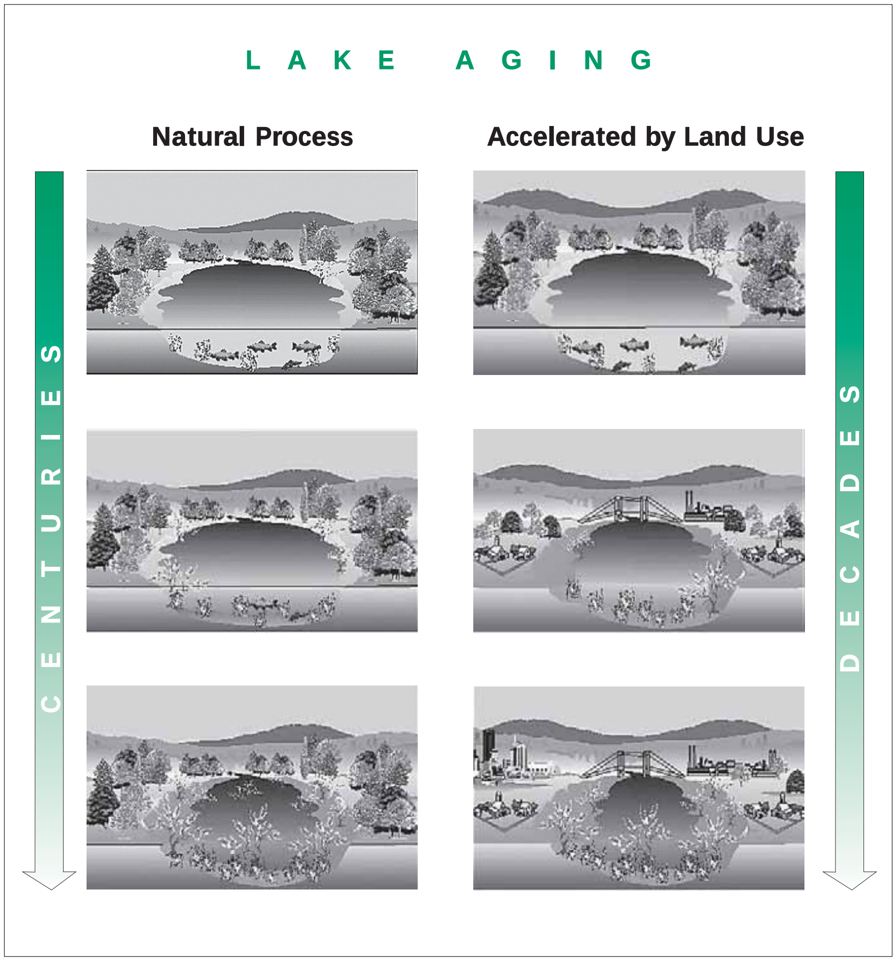

Figure 34-1. Effect of land use on accelerated eutrophication.

Table 34-1. Adverse effects of eutrophication on lakes and rivers.

- Increased biomass of phytoplankton
- Shifts in phytoplankton to bloom-forming species that may be toxic or inedible
- Increased biomass of benthic and epiphytic algae
- Changes in macrophyte species composition and biomass
- Decreases in water transparency
- Taste, odor, and water treatment problems
- Oxygen depletion
- Increased incidence of fish kills
- Loss of desirable fish species
- Reductions in harvestable fish and shellfish
- Decreases in aesthetic value of water body

Adapted from Smith 1998.

contribute to a wide range of water-related problems including summer fish kills, unpalatability of drinking water, and formation of trihalomethane during water chlorination (Kotak et al. 1994, Palmstrom et al. 1988). Consumption of cyanbacterial blooms or water-soluble neuro- and hepatoxins released when these blooms die can kill animals and may pose a serious health hazard to humans (Lawton and Codd 1991, Martin and Cooke 1994).

...P is the primary agent in freshwater eutrophication...

Because of these problems with drinking water treatment, some areas, such as New York State, have done a "U turn" in strategic planning for nutrient management and water quality impacts. It is now cheaper to treat the cause of eutrophication rather than its effects. In the early 1990s, New York City decided it would be more cost-effective to identify and remediate the sources of P in its water supply watersheds rather than build a new water treatment facility. Since then, a variety of programs were established to control nutrient loadings for point and nonpoint sources (NPSs) in the New York City watershed. Because their concern was freshwater quality, P was the main nutrient of consideration.

Recent outbreaks of the dinoflagellate *Pfiesteria piscicida* in the eastern United States may also be influenced by nutrient enrichment (Burkholder and Glasgow 1997). Although the direct cause of these outbreaks is unclear, the scientific consensus is that excessive nutrient loading helps create an environment rich in microbial prey and organic matter that *Pfiesteria* and menhaden (target fish) use as a food supply. In the long term, decreases in nutrient loading will reduce eutrophication and will likely lower the risk of toxic outbreaks of Pfiesteria-like dinoflagellates and other harmful algal blooms. This has dramatically increased public awareness of eutrophication and the need for solutions.

The sources of P and N to lakes and rivers consist of point sources, such as discharges from factories and sewage treatment plants, and NPSs, such as suburban lawns and agricultural lands. On a practical basis, point sources are readily identified and measured, while NPSs are diffuse and difficult to identify and measure. The main NPSs contributing to the P load of water bodies are summarized in Table 34-2. Runoff from uncultivated or pristine land is considered the natural background loading, which cannot be reduced. This source determines the natural trophic status of a lake or river and can be sufficient to cause eutrophication.

In this lesson, P is referred to in its elemental form rather than as P_2O_5, commonly used in fertilizer analysis. The conversion factor from P to P_2O_5 is 2.29. When plant-available forms of soil P (as determined by soil testing laboratories) are discussed, they will be referred to as soil test P (ppm or mg/kg) and in each case the specific method of analysis used will be identified. Based on a six-inch soil depth containing 2 million pounds of soil, the conversion factor from ppm to lbs P/acre is 2.0. For more detailed information on the methods used for soil P testing, how they were developed, and why they vary among regions, see the following articles: Fixen and Grove (1990), Sharpley et al. (1994 and 1996), and Sims (1998).

The Forms and Reactivity of P in Soil

Added P is rapidly fixed by Al, Fe, and Ca compounds in soil...

Soil P exists in inorganic and organic forms (Figure 34-2). Each form consists of a continuum of many P compounds, existing in equilibrium with each other and ranging from solution P (taken up by plants) to very stable or unavailable compounds (the most typical). In most soils, 50% to 75% of the P is inorganic.