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Impact of Phosphorus on Water Quality[1]

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Economic contribution results for Florida's agriculture, natural resources, and related food industries for 2025 included the following:

Industry output or sales revenues of $141.42 billion, and total output contribution of $387.40 billion, including indirect/induced multiplier effects arising from various allied products and services. Food and kindred supported $141.42 billion in sales revenues to Florida's economy in 2022 (UF/IFAS Fast Facts, 2025), the second largest after tourism.

Water quality is an indispensable and critical element for both of these economically significant industries. More than 90% of Florida residents use groundwater for drinking (FDEP, 2014). Streams, rivers, lakes, and ponds create healthy habitats to support ecosystems and wildlife, as well as recreational activities that provide tremendous business opportunities in the state. Overall water quality can be compromised when surface and groundwater water resources receive pollutants from various sources. Among nutrient pollutants, nitrates and phosphorus are the important contaminants for water quality purposes. Protecting the quality of water from contaminants, particularly nutrients, is a top priority for all agencies and stakeholders in the state. This discussion in this article is limited to phosphorus.

The paper highlights the role of phosphorus, interactions with the environment, and its potential impact on water quality. It is intended to serve audiences such as high school students, farmers, and the general public seeking information on the causes and mechanisms of potential negative effects of phosphorus on water quality.

Why Phosphorus (P)?

Phosphorus is the key element of concern because the natural occurrence of P in surface water bodies is minimal. Therefore, even a minute amount of phosphorus entering or becoming soluble in a water body can trigger a significant algal boom (although nitrogen (N) and carbon (C) are also required for algal growth), lowering light penetration and dissolved oxygen levels; it also causes aesthetic degradation of surface water bodies. In some extreme cases, algal blooms can be harmful to human health, for example, when they get into the eyes or when ingested.

Eutrophication

Dissolved nutrients are normally present in small amounts in surface water and in limited concentrations in groundwater. The presence of nutrients, in even small amounts, enables submerged aquatic vegetation to grow and serve as food and habitat for aquatic animals including fish. If the nutrient concentrations in surface waters increase, the growth rate of microscopic algae accelerates and algal growth clouds the water bodies, making it difficult for the vegetation to receive sufficient sunlight and maintain adequate oxygen levels for supporting life. As a consequence, the natural waterborne vegetation may die, leading to a severe reduction in the available habitat area and food for other aquatic life. Also, the death and decomposition of algae during the normal lifecycle will reduce the dissolved oxygen levels in the water. The phenomenon of lowered oxygen levels in water bodies is called "hypoxia," which will negatively impact biological activity in the ecosystem. Survival rates of aquatic life often decrease as a result of hypoxia. This process of water quality degradation is called "eutrophication."

Point and Non-Point Sources of Pollution

A contaminant such as P may enter the water systems at one specific point or one location. This is known as "point source" pollution. One example is discharge from industrial or waste water treatment plant pipelines. Similarly, pollution due to elevated P levels may occur from a large, diffuse area, and not from any one specific location. This is commonly called "non-point" source pollution. Examples of "non-point" source pollution include nutrient losses from manure and waste products spread over large agricultural fields, sediment from eroded soils, nutrient leaching or runoff from residential or agricultural areas, etc. Sediment particles may carry adsorbed P molecules along during runoff. Subsequently, this P may eventually detach and become soluble in water. Because most water bodies are P impoverished, even a minute amount of soluble phosphorus can result in algal blooms and become an environmental concern. Point sources are easily located and controlled, whereas non-point sources of pollution are often very difficult to control in spite of complex management practices. Therefore, prevention approaches are more effective solutions to the problem than post-occurrence management.

Other Potential Sources of Pollution

Groundwater, broadly described as water that flows underground, is partitioned at different depths depending on the geology of the region. In the state of Florida, the Floridan aquifer is the principal source of potable fresh water, and the upper part of the Floridan is the most important portion in terms of total yield of fresh water. However, the upper portion is surrounded by calcareous rock (calcium carbonate) formations. It has been shown that with time, acidic rainfall can dissolve some of the calcium carbonate rock, creating cracks and openings, several meters in diameter in places. These openings are called karsts. Karst geology promotes easy movement of surface water directly into the aquifer, which can become a conduit for pollution. Karst geology is also often characterized by sinkholes, a well-known phenomenon in Florida. Immediately above the upper portion of the Floridan lies a less permeable layer that supports surficial accumulation of a layer of water called a "perched water table." The perched water table is below the typically sandy soil surface and this water predominantly moves laterally becoming another potential source of pollution to the aquifer.

Phosphorus Use in Agriculture

Phosphorus is an essential element for plant growth and agricultural productivity. Fertilizer commonly supplies the crop phosphorus requirement or replenishes P removed from a harvested crop biomass. High value crops demand intensive management in order to remain competitive. In these cases, farmers tend to hedge their bets by fertilizing in excess of the crop requirement determined by a calibrated soil test. Over the long term, this practice will increase soil P accumulation, the risk of off-site movement, and leaching in sandy-textured soils.

Animal agriculture also contributes to increased buildup of phosphorus in soils. Intensive confined livestock production areas or Confined Animal Feeding Operations (CAFOs) accumulate large amounts of both solid and liquid manure, which through land application are used as nutrient sources for crop production. A typical dairy lagoon waste has a 1.2:1 ratio of nitrogen to phosphorus. If manure is applied based on the nitrogen needs of the crop, phosphorus will also be applied in the same proportions irrespective of the soil test based crop phosphorus requirement. Manure transport is often not economical with extended distances, so the surrounding land area generally receives much of the manure, and with the manure comes additional, often unneeded phosphorus. In due course, phosphorus buildup in the soil will result. High levels of phosphorus may saturate the capacity of the soil to hold P, increasing the risk for off-site movement and negatively impacting the quality of the receiving water bodies.

Phosphorus Movement from Agricultural Soils

Leaching and runoff are the main processes by which P is carried into lakes, streams, canals, wetlands, or groundwater. Surface runoff is the portion of rainfall or irrigation that is neither absorbed nor accumulated by the soils but runs down the slope. Along with runoff water, any dissolved phosphorus or phosphorus attached to sediment particles can be carried off site, subsequently reaching the nearest water body.

Leaching is the process by which water moves vertically down through the soil profile and reaches groundwater. Sandy surface soils in Florida have limited ability to adsorb applied phosphorus in agricultural fields, which promotes movement of dissolved phosphorus down the profile beyond the root zone. Due to karst geology, phosphorus-laden water can move upward through freshwater springs, causing eutrophication of surface water bodies. Lateral subsurface water movement also occurs in poorly drained Spodosols, or more commonly, southern Flatwood soils.

Impact of P on Florida Ecosystems

Several unique ecosystems in Florida have been designated by the Florida Department of Environmental Protection as phosphorus-sensitive regions. In these regions, any application of an organic source containing phosphorus should be based on the phosphorus requirement of the crop being grown in that field and not on nitrogen, a typical method for other regions of the state. The Okeechobee Basin, the Everglades, the Green Swamp, and the Apopka Basin are designated P-sensitive areas. Apart from those, several other regions are nutrient sensitive, and any application of P should be based on appropriate soil tests using approved methods recommended by the UF/IFAS Extension Soil Testing Laboratory.

A brief overview of some major eco-sensitive regions affected by phosphorus is provided below.

1. **Lake Okeechobee Basin**

The Lake Okeechobee basin experiences a problem with runoff from the surrounding agricultural and urban areas. The drainage system for the area has been built around the specific needs of urban and agricultural development. Often, excessive amounts of phosphorus and nitrogen enter the lake, leading to increases in lake water nutrients, algal blooms, and a shift to populations of algal plant and animal life that are more tolerant of eutrophic conditions. Currently, the Okeechobee basin provides a habitat for many animals and plants, some of which are endangered. The frequent unnatural flooding and eutrophication of the lake (due to P and N runoff) is causing a negative impact on the health of the natural ecosystem. New technologies and agricultural Best Management Practices are being implemented in the agricultural fields followed by frequent monitoring of nutrient loss to ensure reductions in P loading to the surrounding environment.

2. **The Everglades**

More than 2 million acres in the peninsular region of south Florida, comprising marsh and interconnected wetlands, are called the Everglades (The Everglades Foundation, 2025). Water has been drained and diverted through canals and levees, making way for fertile agricultural lands where several commercial crops are produced annually under intense agricultural management practices. Due to significant increases in P content in these marshes, water quality has been severely impaired. A massive restoration program for the Everglades region, the largest ever in the United States, is underway. Natural water flow to the 2.4-million-acre marsh is being restored, reviving habitat for 60 threatened and endangered species and providing reliable water supply and flood control to south Florida. By requiring implementation of Best Management Practices in the agricultural areas, an estimated 2,678 tons of phosphorus has been prevented from entering the Everglades (FDEP 12/07).

3. The Middle Suwannee River Basin (MSRB)

The MSRB in north-central Florida is characterized by karst geology with a layer of calcareous rocks overlain by highly permeable sandy soil. With time, the underlying calcareous material dissolves forming significant cracks resulting in short circuiting and direct discharge of infiltrating water into the aquifer. After flowing underground, nutrient-laden water can resurface through the openings in the calcareous material as fresh water springs, creating a potential for phosphorus contamination of surface waters. Water quality and Best Management Practices for nutrients in the Suwannee basin are promoted and implemented through the "Suwannee River Partnership," a highly visible and successful partnership comprising more than 65 agencies and entities to minimize or prevent negative nutrient impacts on the environment (The Suwannee Partnership 05/08).

Current Strategies to Minimize the Impact on the Environment

Field scale nutrient management tools such as the Florida Phosphorus Index enable P-loss assessments, where all the factors that lead to losses of P to the environment are qualitatively and quantitatively considered, including the capacity of the soil to retain applied phosphorus. Use of such tools in the formulation, implementation, and monitoring of BMPs for agricultural and urban lands is increasing, and thus potentially minimizing negative impacts from phosphorus on the environment.

Use of standard soil testing methods as predictive and diagnostic tools will help in implement nutrient management effectively at the field-scale. Use of UF/IFAS Standardized Nutrient Recommendations based on soil tests will prevent excess P fertilizer applications to agricultural fields as well as landscapes and home gardens. Information on phosphorus as a plant nutrient, fertilizer recommendations, phosphorus index, research projects, and water quality impact is being offered by the Nutrient Management program in the UF/IFAS Department of Soil, Water, and Ecosystem Sciences. For details, please visit our website at https://soils.ifas.ufl.edu/nutrients/.

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