Modeling Phosphorus in the Environment

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Phosphorus is a key component of fertilizer inputs in plant agriculture and a critical ingredient of diets in animal nutrition. However, elevated levels of environmental P and N have often resulted in algal blooms and accelerated eutrophication of lakes and streams, and degradation of fragile ecosystems of estuaries and coastal waters. In response to increased public concern about the integrity of surface waters and aquatic ecosystems across the USA, states are developing comprehensive nutrient management guidelines, organic fertilizers and animal manure application limits, and stringent permitting processes for protecting soil, water, and air quality. Mathematical models are increasingly used in the evaluation and development of mitigation strategies and management practices to attenuate the impact of agriculture on the environment.

Modeling Phosphorus in the Environment is a timely review of basic processes that affect the movement of P in the environment. The book is a compendium of contemporary research and management models with a module to simulate P transport, including models with the well-recognized acronyms of SWAT, HSPF, AnnAGNPS, ANSWERS-2000, WEND-P, and GWLF. Detailed descriptions are made of how the models allocate, transfer, and simulate transport of dissolved and particulate-associated P in soil and water phases, issues associated with data and model uncertainties, and model performance in assessing P losses under a range of management scenarios. The authors of the 17 chapters are mostly members of the Southern Extension/Research Activity-Information Exchange Group (SERA-IEG) 17, with an appropriate mix of invited outside subject matter expert authors and coauthors. The book chapters are grouped into four sections. Section I, Basic Approaches, consists of six chapters which address the basic processes of erosion, runoff, leaching, stream processes, and sources and estimation of model uncertainty when considering P movement. Section II, Models, covers six specific models and their variations. Each watershed-scale model is presented with a general description of its development and best application. Section III, Phosphorus Indices, Best Management Practices, and Calibration Data, is a collection of topics on field scale assessment of vulnerability to P loss and management issues. The development of Phosphorus Indices to implement a comprehensive nutrient management policy is described and challenges encountered in incorporating such approaches to animal manure management software are illustrated. Supplemental models are presented to extend watershed-scale model use in the process of multi-objective optimization of management options. Guidelines for design and data collection in water quality monitoring projects are provided to fill gaps in data required for model calibration and evaluation. Section IV, Modeling in the future, contains a chapter analyzing needs for future modeling efforts and suggestions for improvement are made for simulating P loss, including estimating uncertainty, quantifying soil P pools and transformations, and fulfilling the need for supporting water quality data.

The organization of the book leads the reader through the steps of identifying important processes and how the models implement the partitioning of labile and particulate P and simulate their transport at the watershed scale. At the other end of the spectrum, the book presents discussions of how management models have incorporated statistical and empirical knowledge into frameworks to index vulnerability to P losses and in decision support tools to develop best management practices. A detailed subject index, along with the depth of the literature review associated with each chapter, should help the reader gain a fundamental understanding of processes contributing to environmental P movement. The text brings together in one document scattered information on transport models for comparison. It should be an informative tool for an audience at the post-graduate level, to researchers, engineers, practicing consultants, resource managers, and planners on the development and use of models in studies of P transport in the environment or in assessing the effectiveness of management strategies.

While transport mechanisms of dissolved and particulate P are thoroughly examined, the book does not extensively address the speciation of P forms that exist in soil and water systems, and at the soil–water–air interface. Phosphorus is used as a generic term in the title of the book as well as in the models, regardless of the P species’ chemical formula or chemical classes. Formal discussions of soil P speciation and P pools were briefly made in a sub-section of chapters discussing the SWAT model and future modeling needs. Many of the soil P algorithms and geochemical modules in the models were based on concepts developed in 1980s, embodied in the Groundwater Loading Effects of Agricultural Management Systems (GLEAMS) which was later transferred to the Erosion/Productivity Impact Calculator (EPIC) model. The algorithms were rooted in our understanding of processes affecting the behavior and fate of organic pesticides. Although many advances have been made in the understanding of the biogeochemistry of inorganic and organic forms, factors influencing P speciation and release mechanisms over the last two decades, current P models have yet to substantially link these processes with surface transport and movement in the vadose zone. Additional reading of other works will be necessary to gain a more comprehensive understanding of the biogeochemistry and environmental behavior, particularly of a major group of soil P species, that is, phosphate monoesters of inositol. Translating the knowledge of inorganic and organic release mechanisms into consistent algorithms that link them to transport processes remains a challenging task that will be a necessary development in future P models.

Overall, Modeling Phosphorus in the Environment adds to the relatively small body of recent material dedicated to modeling P and will prove a useful tool to organize our current understanding of processes affecting P movement in the environment. For the wide range of needs of end-users, the book presents in clear language the basic assumptions and the approach taken by each of the six models for readers to select the model that best meet their needs and provides guidance on data requirements, availability, or accessibility of the chosen model.

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