Natural Systems for Wastewater Treatment: Course Material and CD-ROM Development

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INTRODUCTION

Natural systems for wastewater treatment are biological, land-based approaches used to remove pollutants from organic solid wastes and wastewaters. Examples include stabilization ponds and lagoons, artificial wetlands, aquatic plant systems and land treatment systems. Natural systems have gained attention and acceptance in recent years because they integrate waste treatment into the environment in a positive fashion. Recent research and applications of natural systems have generated considerable information for management of potential pollutants from industrial, municipal and agricultural materials.

Natural systems are the most widely used of waste treatment process for agricultural applications. These systems typically require fewer operational personnel, consume less energy and produce less excess biomass than conventional wastewater treatment systems. Where sufficient land of suitable character is available, natural systems are often the most cost-effective option for both construction and operation. Thus, they are better suited for agricultural industries and small rural communities. As the pollution prevention focus moves to nonpoint sources, natural systems will play more important roles in dealing with agricultural waste treatment and water quality management.

Currently students in agricultural, environmental and natural science disciplines have little opportunity to learn about waste management and pollution control. These topics are usually addressed incidentally within general courses. For engineering majors, environmental engineering courses cover waste treatment in depth but natural treatment processes and systems are rarely addressed. Therefore, a timely opportunity exists for a new course that addresses the growing demand for information about natural treatment systems.

This paper summarizes a USDA Challenge Grant project to design a curriculum and develop materials about natural treatment systems in the area of Biological and Agricultural Engineering. The goal of the project is to develop a new course that better prepares undergraduate students of biological/agricultural engineering and other agriculture and natural resources majors to meet the challenge that agricultural industries face in dealing with environmental issues. The course integrates current theoretical principles and practical experiences in the use of natural systems for agricultural waste treatment and water quality management. A description of the course, its development processes and preliminary results of the project are presented.

PROJECT OBJECTIVES

The objectives of the project are to:

- Summarize and evaluate current research and published information on natural systems for agricultural waste treatment and water quality management.
- Develop course material in conventional printed form with supporting/reference material on CD-ROM for use in instruction and review.
- Conduct a trial offering of the class.
- Review, revise, finalize and disseminate project results in the form of a class package.

COURSE AUDIENCE

Early in the development of this course, it was decided that the course should not be limited to engineering students. Because of the broad interest in natural treatment systems and its many applications, the course will benefit non-engineering majors in agricultural, environmental and other natural sciences. Given that the current design of natural systems is largely empirical, the general design and evaluation can be accomplished without complicated engineering calculations. The course should be approachable by students with the basic math and science training that natural science majors typically receive. Students are anticipated from departments of Biological and Agricultural Engineering, Environmental Science, Animal Science, Soil and Crop Science, Natural Resources, Civil and Environmental, and Chemical Engineering departments.

Because the course was intended to include theory and design based on a general foundation of soil science, biology, chemistry and mathematics, a senior-level designation was originally

anticipated. Upon discussion with the project members, the course has evolved to a more flexible format. The main core course will be taken by the engineers and non-engineers alike, while an optional design laboratory will be available to engineers only. The separation of "hard" design into a laboratory section was thought to avoid undue complication and remedial learning that would be necessary for students unfamiliar with engineering design procedures.

COURSE CONTENT

The natural systems course is divided into two sections; Part 1 deals with basic introductory material, theory, design and evaluation procedures; Part 2 covers specific applications of natural systems. As envisioned, Part 1 will be presented by the instructors with Part 2 emphasizing a self-learning approach within a design team. Materials for the course will be included in an overall course manuscript with supplemental information supplied on CD-ROM.

To date, the course manuscript consists of the following chapter topics and subject matter:

> **Part 1 - Natural Treatment Systems: Mechanisms of Action and Design Considerations**
> Part 1 of the course gives a firm theoretical background related to the science and engineering of natural treatment systems. The students learn the science of basic treatment mechanisms that occur and engineering methodology to promote, optimize and manage such treatment to a beneficial endpoint.

> **Chapter 1, Introduction**
> The introductory material covers problems created with release of untreated wastes and wastewaters into the environment. A rationale for using natural systems as environmentally benign waste management tools is also discussed. Students are introduced to the various types of natural systems covered in the course and the relationship of biology, chemistry and engineering to treatment mechanisms at work in natural systems. Basic design rationale is also reviewed.

> **Chapter 2, Basic Waste Treatment Mechanisms In Natural Systems**
> Mechanisms of treatment general to all types of natural systems are covered initially with later specific reference to waste constituent fates. The chapter includes:
> A. Natural Waste Treatment Mechanisms
>> 1. Physical - filtration, sedimentation, dilution, evaporation, leaching, runoff and erosion

2. Chemical - adsorption, ion exchange, precipitation, chelation, volatilization, photolysis, equilibrium and pH effects
3. Biological - aerobic degradation, anaerobic degradation, mineralization, anabolic vs. catabolic processes, immobilization, nitrification, denitrification, plant and animal assimilation, transpiration, photosynthesis and oxygenation, algae as biomass source, and bioconcentration

B. Fate of Specific Waste Constituents in Land Treatment Systems

Water, organic matter (BOD/COD), cations and anions, salts, nitrogen, phosphorus, heavy metals, oily materials, pathogens, other specific constituents (e.g. boron, chlorides)

Chapter 3, Design Considerations

This chapter introduces the student to a general approach to design and implementation of natural treatment systems. After covering typical waste characterization, an emphasis is placed on limiting-factor design, including hydraulic, nutrient and metal loading in an overall evaluation of assimilative system capacity. Additionally, design differences in soil and aquatic systems are discussed along with site-specific factors and monitoring and management issues.

Part 2 - Natural Treatment System Types and Applications

Part 2 of the course looks at specific types of natural treatment systems with an emphasis towards quantification and design. The application of the various treatment mechanisms, discussed in Part 1, are now studied specific to treatment system type. Each chapter of Part 2 covers a separate process from the aspects of design, process limitations, operation and maintenance, and other considerations applicable to a particular waste or location. Supplemental information related to Part 2 (included on CD-ROM) details real-world case studies relative to a specific waste type produced in agricultural industries (e.g. dairy, swine) in addition to on-site systems for small wastewater flows and systems for non-point pollution control.

Chapter 4, Waste Stabilization Ponds and Lagoons

A. Introduction - definitions and distinctions, system function, types of ponds and lagoons, design considerations and methods
B. Process Analysis and Design - 1) retention, storage and sedimentation ponds; 2) aerobic lagoons; 3) anaerobic lagoons; 4) facultative lagoons; 5) mechanically aerated lagoons (how they differ from natural lagoon systems)

C. Performance and Limitations - organic removal, nutrient removal, pathogen removal, leakage, liners

D. Operation and Maintenance - inlets, outlets, sidewall and bank maintenance, solids removal, nuisance rodents and aquatic plant control

E. Other Considerations - siting, waste applicability

Chapter 5, Wetlands Systems

A. Introduction - system type and function, history, current state of application

B. Process Analysis and Design - reaction kinetics and reactor type assumptions, design procedures, design criteria, function and selection of plantings

C. Performance and Limitations - organic removal, nutrient removal, pathogen removal and inactivation, other pollutants

D. Operation and Maintenance

E. Other Considerations

Chapter 6, Aquatic Plant Systems

A. Introduction - system type, history

B. Process Analysis and Design - aquatic plants and their characteristics related to system design, duckweed, hyacinth

C. Performance and Limitations - organic removal, nutrient removal, pathogen removal and inactivation, other pollutants

D. Operation and Maintenance

E. Other Considerations

Chapter 7, Land Treatment Systems

A. Introduction -rationale, history, current state of application

B. Process Design - soil as treatment medium; level 1 feasibility study; level 2 limiting factor design; system design types 1) overland flow, 2) rapid infiltration, 3) slow-rate, 4) direct application, 5) subsurface infiltration

C. Performance and Limitations - hydraulic loading, organic loading, nutrient loading, metals loading, pathogen removal and inactivation, other pollutants

D. Operation and Maintenance - run-on, runoff, monitoring

E. Other Considerations

Chapter 8, On-Site Wastewater Treatment Systems

A. Introduction - system type and function, history

B. Process Analysis and Design -septic tanks and soil absorption fields, aerobic treatment units, sand filters

C. Performance and Limitations - organic removal, nutrient removal, pathogen removal and inactivation, other pollutants

D. Operation and Maintenance

E. Other Considerations

Chapter 9, Nonpoint Source Pollution

A. Introduction - definitions, regulations, waste constituent types and impacts

B. Process Analysis and Design - hydrologic considerations, sediment transport, contaminant transport, water/soil/air interfaces, volatilization, process types 1) sediment control structures, 2) vegetative strips, 3) vegetated waterways, 4) terraces, 5) detention structures

C. Performance and Limitations - passive vs. active treatment and control

D. Operation and Maintenance

E. Other Considerations

SUPPLEMENTAL COURSE MATERIALS - CD-ROM

Supporting material, including specific case studies will be included on a CD-ROM for ease of use and dissemination. The CD will be accessed using Adobe Acrobat document viewer, included on the disk.

Students will be encouraged to access the information on the CD on a self-study basis as both background and detailed information relative to the various types of treatment system. The use of the CD is advantageous because of its capacity for data storage in a convenient-to-use format. The CD will contain information on natural system configuration, design, operation, performance, costs and evaluation. Its contents will include:

The North American Wetland Treatment Systems Database (available through EPA)
Case studies:
- Natural systems for nonpoint source pollution control
- Food processing waste treatment
- Dairy waste management and treatment
- Swine waste management and treatment
- Poultry waste management and treatment

- Aquaculture waste treatment
- On-site waste treatment for small communities

COURSE EVALUATION

Evaluation of the course is planned at several stages during its development and from a number of sources. These sources include peer review, industry review, student review and results of a proposed workshop on the course. In March 1997 (at the time of writing this paper), a detailed outline of the course content was sent for peer review to various universities and related industries across the US. Feedback from the outline review will guide changes in content or presentation style. Once the final course manuscript and accompanying CD-ROM are fully developed, they will also be sent out for a similar peer review.

The course is scheduled for an initial trial offering in Fall 1997, jointly at Washington State University and the University of Idaho. Because the two universities are only eight miles apart, a joint offering is possible. Student evaluation of the course will play an important role in outcome-guided feedback to make changes and corrections for subsequent offerings. Feedback, through written evaluation and open discussion with the students, will be solicited for both course content and presentation style.

The final evaluation step will come from results of a planned two-day workshop on the course offering in January 1998 at Washington State University. Peer reviewers from other universities and industry, prospective users of the course manuscript and project personnel will be invited to participate. Comments and suggestions from the workshop will be incorporated into the final version of the course manuscript and CD-ROM.

SUMMARY

Many Agricultural Engineering Departments have broadened their curricula to include Biological Engineering. Also, nonengineering disciplines are increasingly concerned with waste management and treatment. As a result, there is an urgent need for new courses to support the curricular modifications. Environmental-related education is a major component that many new curricula include because of the environmental impacts of agricultural activities and the corresponding demand of agricultural industry to our educational programs.

A proposed course for the new Biological Engineering curricula entitled "Natural Systems for Wastewater Treatment" is being developed as a collaborative effort between Washington State

University, the University of Idaho, and Texas A & M University, supported by the USDA Higher Education Challenge Grant Program. The course will integrate the current theory and practical experiences in the use of natural systems for agricultural waste treatment and water quality management. The course is intended for undergraduates majoring in Biological/Agricultural Engineering, as well as other agricultural and natural resources majors. The main topics covered in the course are 1) advantages and limitations of natural systems, 2) system design and evaluation, and 3) application of different types of natural systems. The course is being developed by summarizing and evaluating the current research and publications in natural systems for agricultural waste treatment and water quality management and by developing conventional printed instructional material and associated supporting/reference materials in a CD-ROM format.

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